

BBC A PSYCHOLOGIST'S GUIDE TO BEATING THE BURNOUT

Science Focus

MEANING OF LIFE NOT INCLUDED

How to start
STARGAZING AT HOME

Discovering the
SEASONS OF THE HUMAN BODY

Finding answers to
VACCINE SAFETY MYTHS

MYSTERIES OF THE UNIVERSE

Why are monster black holes at the heart of every galaxy?

Why is there something rather than nothing?

Where is two thirds of the Universe?

Why haven't we seen alien life?

What is dark matter?

Does time exist?

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Health

Michael Mosley on how to
lower your blood pressure

Dinosaurs

How they came to
rule the planet

Food

Restaurant puts 'no-kill'
meat on the menu



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Thank you, Sylvia

Sylvia left a gift in her Will to help conquer Stroke

The first we knew of Sylvia was when we received notification of the gift she'd left us in her Will. Shortly after, a beautiful story of a much-loved woman began to unfurl.

Friends remembered Sylvia's kind-heart and her wish to help others. She spent part of her adult-life caring for her mother, and developed a passion

for medicine. Becoming a medical secretary was her next step and, in the course of her career, she discovered the devastating impact a stroke could have on people and their families. She saw that research and treatment were vastly under-funded, and she decided to remember the Stroke Association in her Will.

Sylvia's gift has helped fund our work to conquer stroke. She's supported research to prevent and treat stroke, and she's helped care for survivors. And that's something you can do too – in the same way.

If you would like to learn more about remembering the Stroke Association in your Will, please get in touch.

**Call 020 75661505 email legacy@stroke.org.uk
or visit stroke.org.uk/legacy**

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Stroke
association

FROM THE EDITOR



It's our January issue and we wanted to kick off the year with a big bang, so we asked one of our favourite writers, Marcus Chown, to give us a concise guide to nothing less than the biggest mysteries in the Universe. No one writes quite like Marcus, so grab yourself a hot drink, curl up in a corner away from wintry chills and turn to p46.

Speaking of the weather, researchers at Stanford University have discovered that the human body has its own set of seasons. At particular times, molecules and microbes inside us fluctuate to meet to the changing environment around us. It's a fascinating piece of work that demonstrates the kinds of discoveries we might make with a multiomics approach to medicine: that is, being able to study and compare many different facets of a person's health, such as their genetics, microbiome and hormones, as they fluctuate day in day out through the year. Get the whole story on p66.

And finally, 2020 was a tough year for all of us. So over on p54 we asked journalist Amy Fleming to see what some of the world's leading experts on stress and exhaustion can advise on beating the burnout. There's some great advice in there.

Enjoy the issue!

Daniel Bennett

Daniel Bennett, Editor

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ON THE BBC THIS MONTH...



Cheetah Family And Me

Gordon Buchanan meets a family of wild cheetahs in the Kalahari wilderness, South Africa, and witnesses their fraught world.
BBC iPlayer

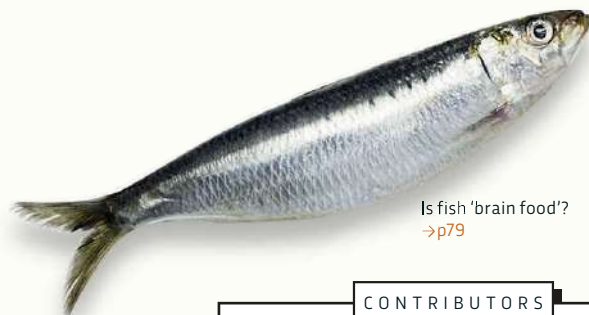
CrowdScience

The *CrowdScience* team will be investigating whether there are any downsides to deep cleaning, the effect of alcohol on fertility, and more.
BBC World Service, Fridays, 8:30pm

I Am Greta

From her first school strike outside Swedish Parliament to her wind-powered journey across the Atlantic Ocean, the life of climate activist Greta Thunberg is revealed in this documentary.
On BBC iPlayer

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FÖR
KLIMATET



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→p79

CONTRIBUTORS



AMY FLEMING

We're all feeling pretty rubbish at the moment, thanks to pandemic burnout. Science and health journalist Amy offers some ways to help you feel better. →p54



SUSAN D'AGOSTINO

Susan is a maths professor turned writer. She investigates the patterns that scientists uncover when they study the personal data modern medical tech can provide. →p66



ABIGAIL BEALL

Astronomy needn't require a telescope and a stack of star charts. Abigail, a science writer and urban astronomy expert, reveals how to spot the night sky's wonders. →p72



MARCUS CHOWN

Marcus, a cosmology author and former radio astronomer, takes a tour of the black holes in our knowledge of the cosmos. You'll need a coffee for this one. →p46

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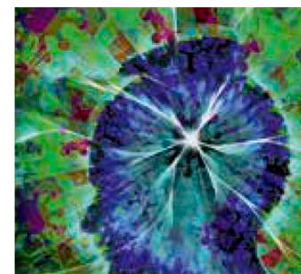
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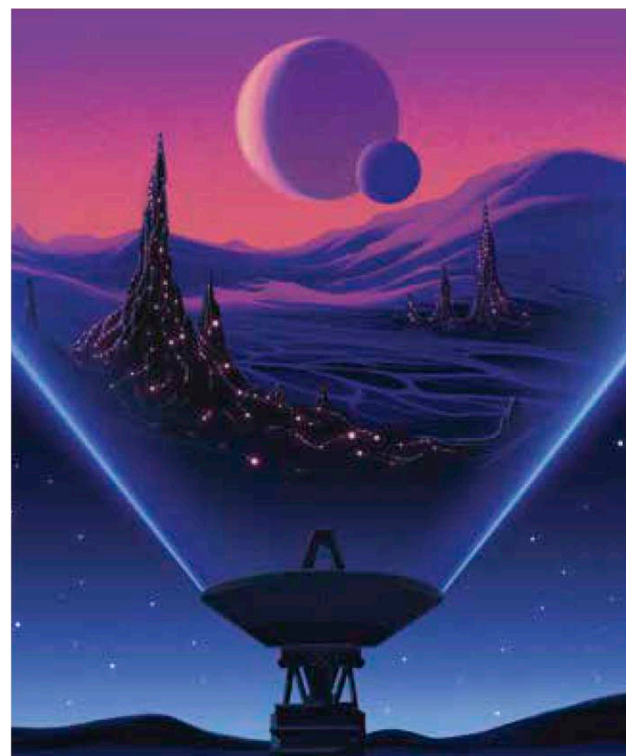
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“HACK THE PAST AND DESIGN THE FUTURE NOW, SO WE CAN LIBERATE THE NEXT GENERATIONS FROM US”

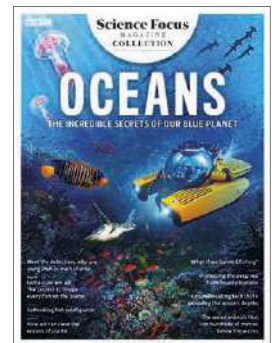
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**SPECIAL ISSUE****OCEANS: THE INCREDIBLE SECRETS OF OUR BLUE PLANET**

In this special edition, the experts from *BBC Science Focus* don their diving kit and take the plunge into the depths of the oceans, to reveal more about the incredible world beneath the waves.

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EYE OPENER

Buzz off!

WASHINGTON STATE, US

In October, the US's first confirmed nest of Asian giant hornets (*Vespa mandarinia*) was destroyed by scientists in Washington state. The invasive insects are also known as 'murder hornets' as they are voracious predators of honeybees, which are important pollinators of crops.

The team attached tiny tracker devices to some worker hornets, which led them back to the nest in a tree cavity. The vacuum device seen here was used to extract the insects, before carbon dioxide was pumped into the tree to anaesthetise any stragglers. The scientists had to wear protective suits, as the hornets can sting multiple times and are able to spray venom.

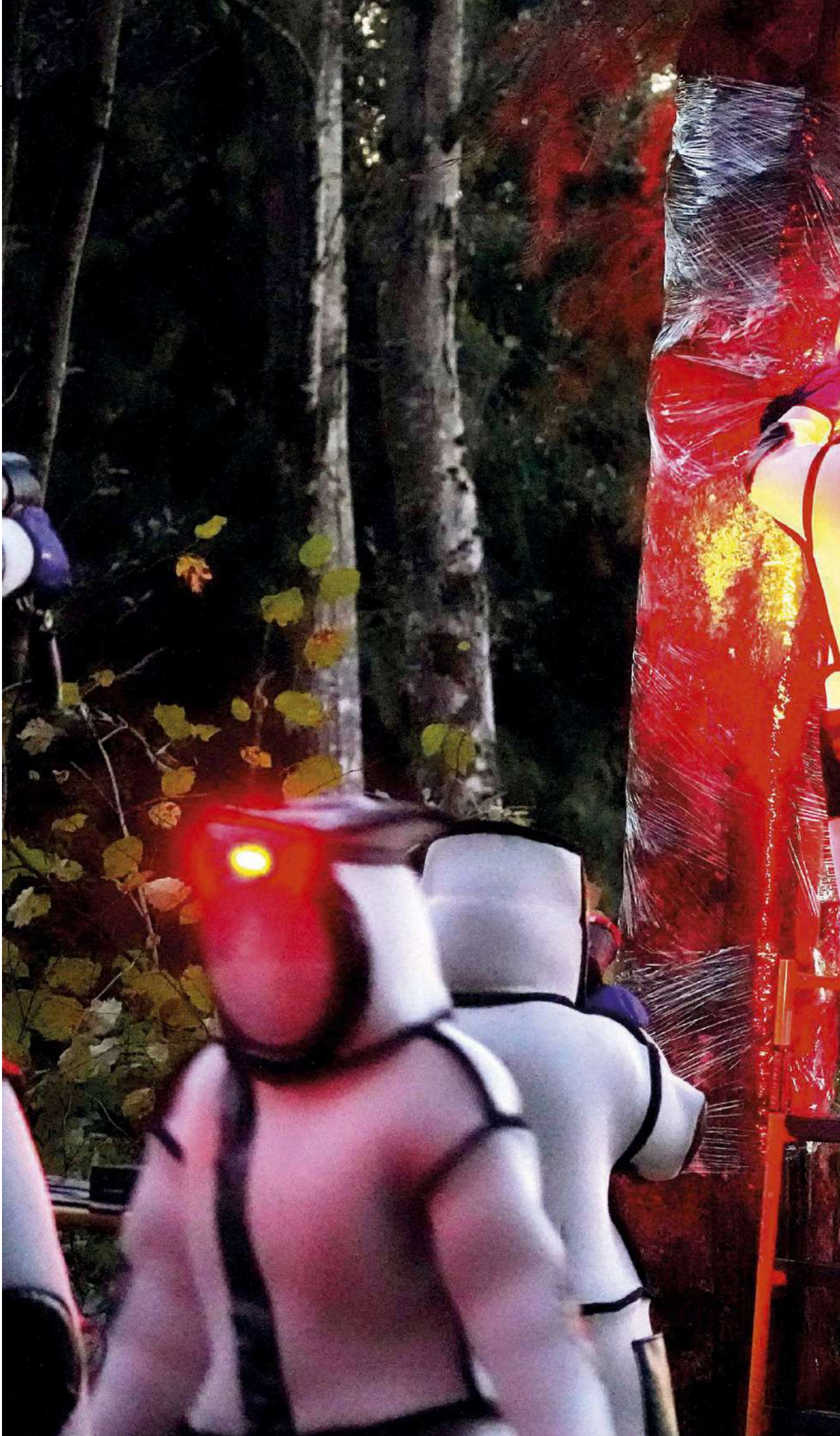
While US bees cannot defend themselves against the hornets, Japanese honeybees, having evolved alongside the predators, have a trick to ward off attacks: when a 'scout hornet' first enters their hive, the bees form a tight ball around it, increasing carbon dioxide levels and raising the temperature to kill the intruder.

GETTY IMAGES

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EYE OPENER

A salt on the senses

TURDA, ROMANIA

The underground salt mines in Turda city, Transylvania, are no longer used to extract everyone's favourite chip seasoning – instead, the enormous caverns have been transformed into an impressive tourist attraction.

It's possible that salt was mined from Salina Turda as far back as the Roman era, but the earliest definitive records date back to the 13th Century. While salt extraction stopped in the 1930s, the mines were not forgotton. In WWII they were used as an air raid shelter, and then later as a storage unit (for cheese, apparently). Now, though, Salina Turda includes a Ferris wheel, a mini-golf course and billiards tables.

Some people believe that spending time in salt mines is beneficial for our health – a form of alternative medicine dubbed 'halotherapy'. While there is no scientific basis to these claims, it cannot be denied that the mines are an impressive environment to explore.

ALAMY

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EYE OPENER

Ice planet

NOACHIS TERRA, MARS

Below the familiar dusty red surface of Mars lies a landscape perhaps even more alien. In addition to Mars's two polar ice caps, which we can sometimes see through a garden telescope, it is thought that around one-third of the planet is covered in subsurface ice. The blue-coloured ice is visible in this image as it had become exposed on a cliff face in the Noachis Terra region, near the Hellas Planitia crater.

Scientists are studying this Martian ice in the hope of revealing more about the Red Planet's ancient climate, but it could also hold the key to future crewed missions. Water is crucial to the success of such missions, not only for drinking, but also for making rocket fuel. This would reduce payload weight, as future astronauts could make fuel on Mars for the return voyage back to Earth.

The honeycomb-like pattern seen here is likely caused by the cooling and contraction of the ice, creating thin cracks that develop and coalesce over time.

NASA/JPL

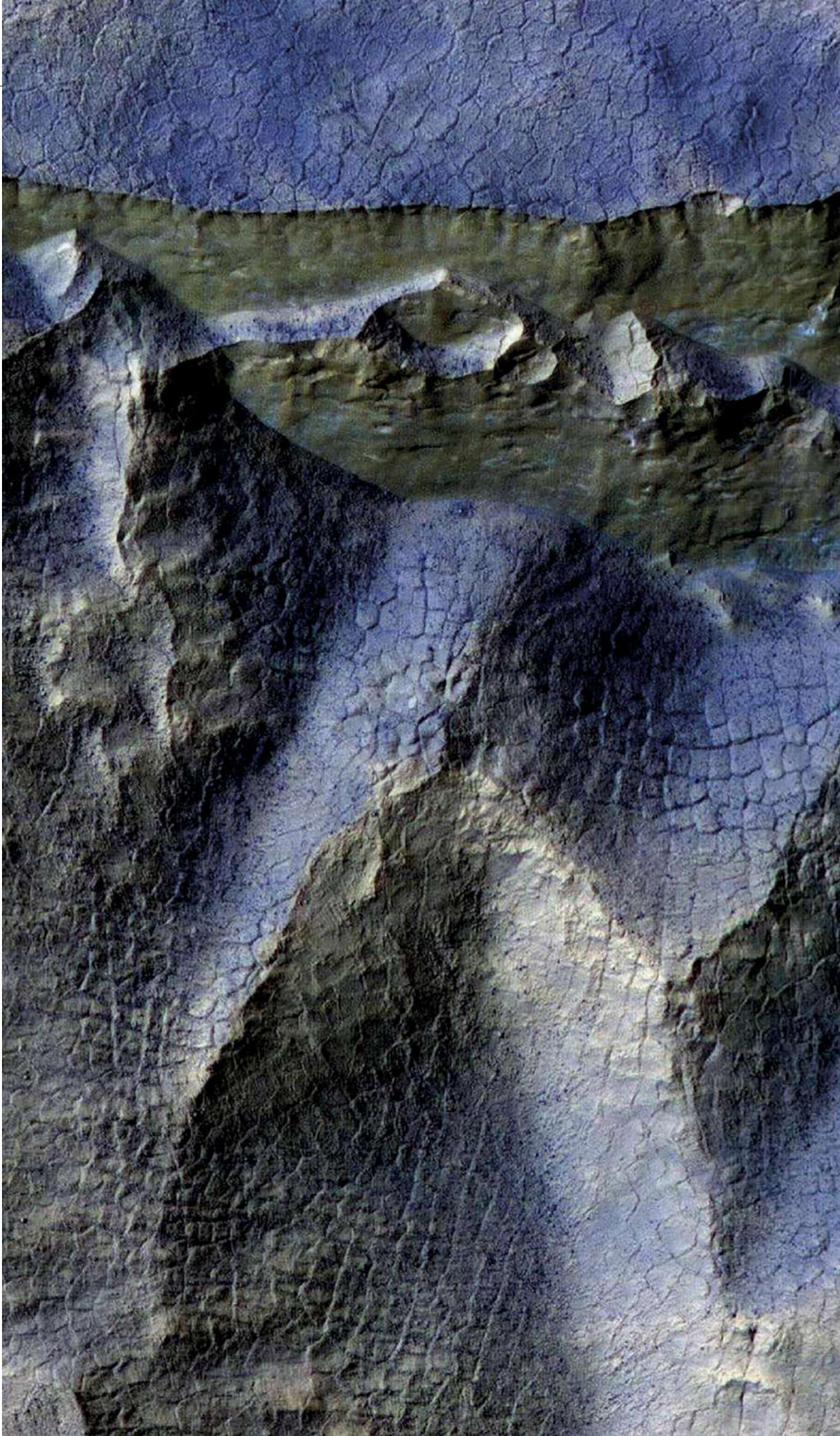
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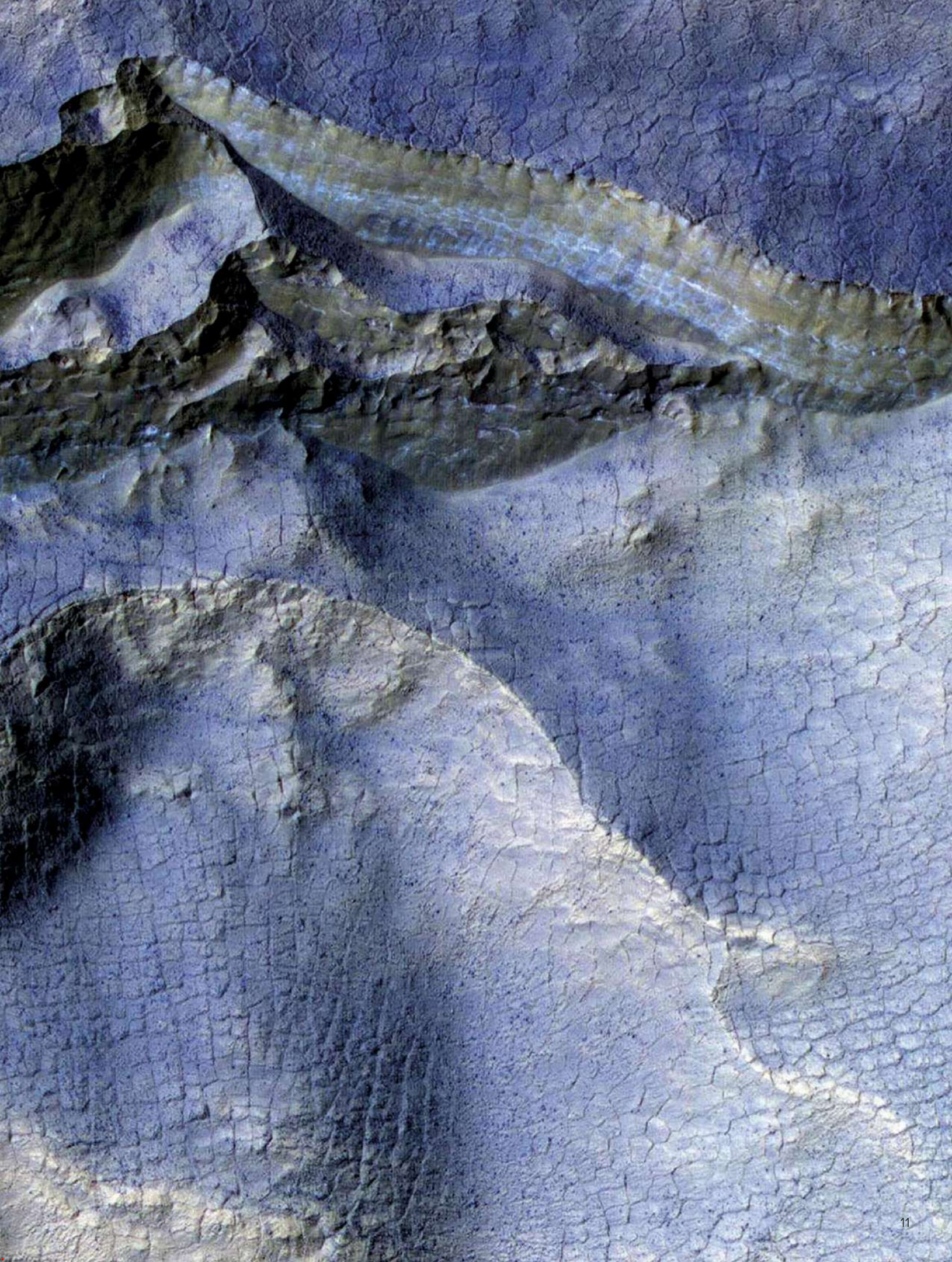


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A low-angle, upward-looking photograph of a forest. Several tall, slender tree trunks with reddish-brown bark rise from the bottom of the frame towards the top. The canopy is dense with bright green foliage, and patches of a clear blue sky are visible through the leaves. The text "Shoot the sequel with MPB" is overlaid in white, sans-serif font on the left side of the image.

Shoot the sequel
with MPB

CONVERSATION

YOUR OPINIONS ON SCIENCE, TECHNOLOGY AND BBC SCIENCE FOCUS

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LETTER OF THE MONTH



Plastic-henge

After reading your article about Prof Trevor Cox's work at Stonehenge (October, p22) I found myself asking, "what's missing from this experiment?"

Many years ago, I qualified as a stonemason. We learned how to tell if a stone had any flaws: you take your chisel and bang it against the stone: the sound resonance will either ring true and clear, like flicking a crystal glass, or give a dull thud if the stone is flawed. So, how can any sound reflected from a piece of printed plastic give a true indication of the actual sound, especially from the harder bluestones from the Preseli Hills? I'm sure Cox thought of this, but it wasn't mentioned in the

article. I'd be very interested to know what he thinks.

Gary Sansom

Our experiments were not concerned with how the stones might respond to being struck, instead we determined how voices and musical sounds passing through the air were reflected from the structure.

Acoustic scale models frequently use materials different from the original because we choose stuff that is easier to work with. But it is vital that the materials respond to sound in the same way as would happen in the real Stonehenge, allowing for the fact we test at 12 times the frequency in a 1:12 scale model.

To replicate the acoustic properties of stone, we used materials that were heavy and non-porous, like 3D-printed hollows filled with concrete. Matching ground conditions was more problematic because the conditions are uncertain. Ground reflects differently depending on how compacted it is and also on how saturated by water it is. We decided to model the ground as compacted, because moving many tonnes of rock around would have compressed the ground.

Prof Trevor Cox, *acoustic engineer*

WRITE IN AND WIN!

The writer of next issue's *Letter Of The Month* wins a pair of **Skullcandy Push Ultra earbuds**. These waterproof earbuds can withstand the sweatiest of workouts and can survive being submerged in a metre of water for 30 minutes. Plus, their rapid-charging capability gives you two hours of charge in 10 minutes. skullcandy.co.uk



Mother Alexa

In your article on the capabilities of AI and Alexa (November, p43), you talked about how smart technology not only responds to human commands but is also 'predictive' and 'proactive' in its actions.

As humans are naturally unpredictable beings, is it really possible for an AI system to calculate all possible circumstances and carry out the correct actions?

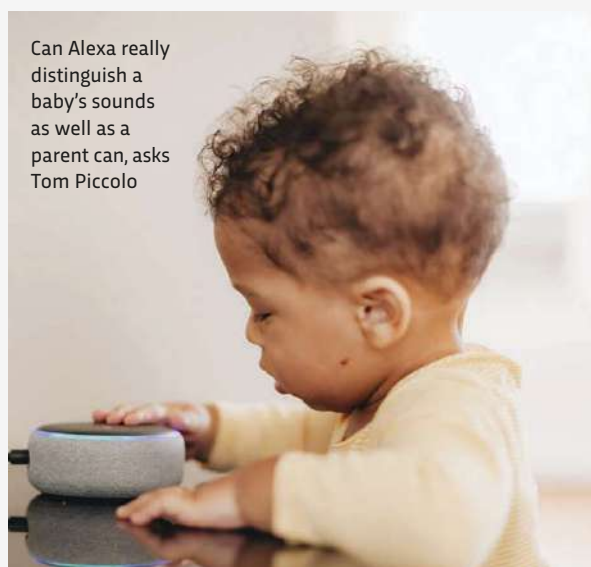
You wrote that the system can develop and adapt – like when a baby is crying, Alexa turns on the light. What if the baby is crying because it is hungry? A parent can develop an acute knowledge of the different sounds a baby makes and what they mean, often instinctively. Would it really be possible for an AI system to memorise each individual crying noise and determine what each one means?

Tom Piccolo

Fuelling the flight

As a new reader I am hooked on your scientific outlook and sharing of new research. But I

Can Alexa really distinguish a baby's sounds as well as a parent can, asks Tom Piccolo





“WE, AS A SOCIETY, ARE DUTY-BOUND TO PROTECT OUR CHILDREN, WHATEVER SIZE THEY ARE, FROM THE CHOICES THEY ARE HARDWIRED TO MAKE IN THIS CURRENT FOOD ENVIRONMENT”

DR GILES YEO, P36



The XB-1 craft is cool, but it's another source of pollutants, says Ravina

would have liked a bit more information about the XB-1 development (December, p20), especially given our current climate crisis.

I don't see how encouraging resources and testing simply for passenger supersonic flight is a responsible thing to do. Yes, the technology is there. Yes, the aircraft look amazing. But is it worth the waste in fuel, the losses encompassed in supersonic flight? I think this is a case of seeing the bigger picture and understanding the world is not in need of another pollutant.

Ravina

Helping hedgehogs

I was very pleased to read your article about hedgehogs (December, p28) which others will, hopefully, use to help protect this lovely animal. I had one small question about feeding them, though. I've come across research that suggests mealworms are the

cause of metabolic bone disease and should be avoided. Is this true?

Les Pallett

Despite much discussion online, there's still no scientific link of hedgehogs being fed mealworms getting bone defects or other problems. But to be on the safe side, always offer food like mealworms in moderation, as a supplementary treat to the hogs' wild diet.

Ben Hoare, wildlife writer



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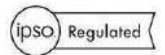
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Early warning systems

Leave a gift in your Will to Cancer Research UK and help its scientists find new ways to detect cancer earlier

Diagnosing cancer earlier saves lives. It increases the chances of a successful treatment and reduces the likelihood of long-term side effects.

But finding new ways to spot cancer early can be difficult, which is why nearly half (46%) of cancer patients in England are diagnosed when the disease is already advanced. Thanks to its supporters, Cancer Research UK is providing funding for scientists who are developing new devices to detect the early signs of cancer.

Devices like the Cytosponge – a new way to test for Barrett's oesophagus, which is a condition that can increase your risk of developing oesophageal cancer. Currently, the test for Barrett's oesophagus is an endoscopy, a procedure that's both invasive and expensive. The Cytosponge test relies on a small sponge that collects cells from the patient's oesophagus; it's cheaper, easier to perform and, according to the results of clinical trials, can identify up to 10 times more people with Barrett's oesophagus than current GP care.

The Breath Biopsy®, a breathalyser, is another new technique being trialled by Cancer Research UK-funded scientist Professor Rebecca Fitzgerald, in collaboration with Owlstone Medical. It detects volatile

molecules in a person's breath that can indicate early-stage cancers, including bladder, breast and brain tumours.

New technologies like these are valuable tools for beating cancer, but they need funding. Without it doctors, scientists and researchers are unable to develop and test them. Cancer Research UK funds nearly 50% of all cancer research in the UK and the best way you can contribute to that funding is through a gift in your Will.

Gifts in Wills fund over a third of Cancer Research UK's work. They're vital to the charity and without them a lot of life-saving work wouldn't happen. That's why Cancer Research UK is so grateful to all the amazing people who help this way.

There are various types of gifts you can leave in your Will, such as a specific amount or item, but a 'residuary' gift is the most valuable. A residuary gift is a share or percentage of your estate that's inflation-proof, so it will never lose value.

Catching the disease early offers the best chance of successful treatment. To do that we need better, which needs research, which needs funding, which needs you.



Coming back from COVID-19

The COVID-19 pandemic has had a serious impact on Cancer Research UK. Funding has fallen and future research is at risk. But this research saves lives. 1 in 2 people will get cancer in their lifetime, which is why the charity is determined to continue its life-saving research. This is research that will make treatments kinder, less disruptive and ultimately, will save lives. But to save lives tomorrow, Cancer Research UK needs your help today. Pledge right now to leave a gift in your Will to Cancer Research UK and you could make a real difference to future generations.



To find out more, request a free Gifts in Wills Guide. Visit cruk.org/willsguide or call 0800 077 6644



Together we will beat cancer



FIRST BREATH

Independence begins with a lungful of air **p19**

FROM FINS TO LIMBS

Funny bone holds the key to the shift from sea to land **p20**

WORMS IN SPACE

Invertebrates show us how microgravity alters DNA **p21**

A NOSE FOR RUNNING

Mice bred for running have different noses **p22**

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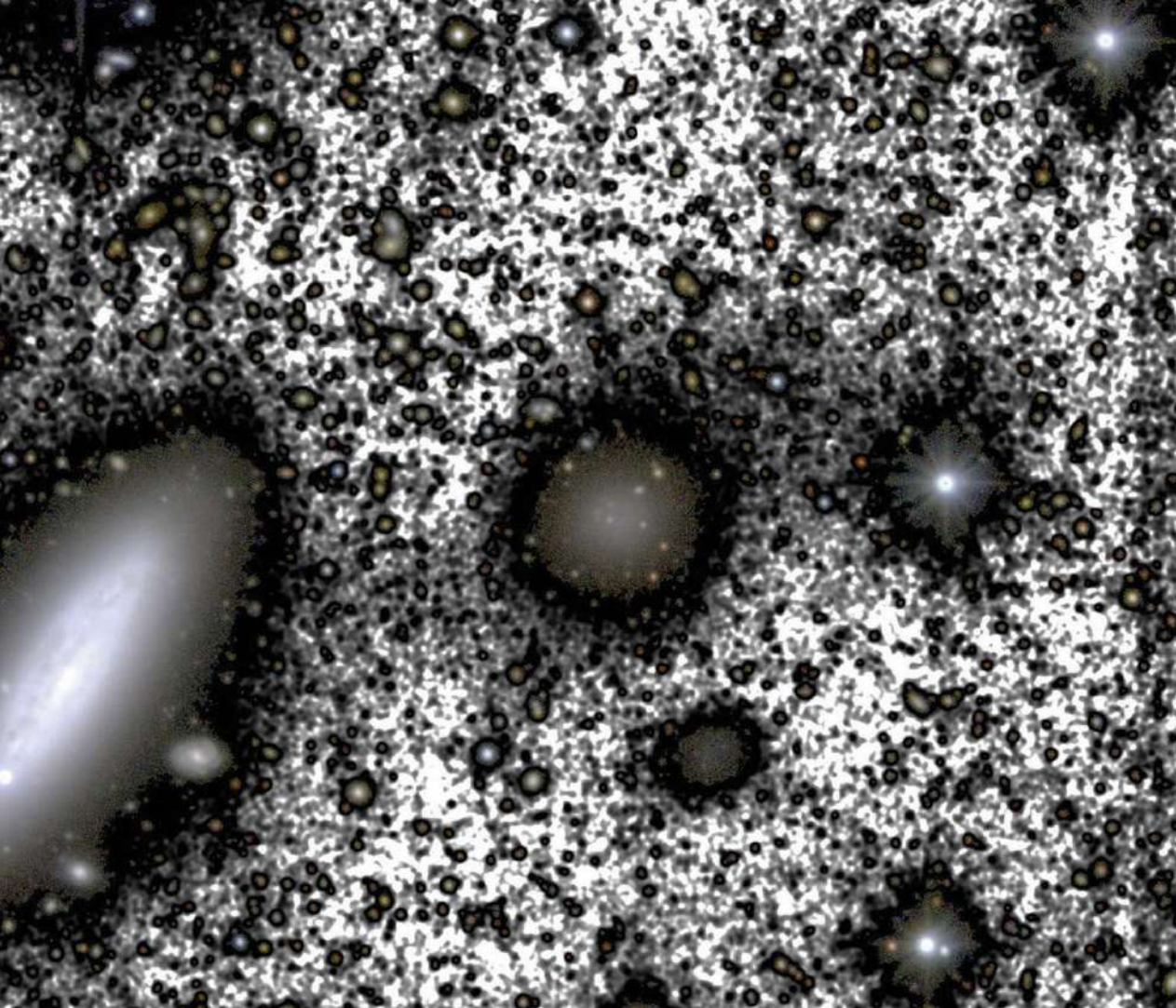
NEIGHBOURING GALAXY TO BLAME FOR BIZARRE CASE OF MISSING DARK MATTER

Observations made by the Hubble Space Telescope solves two-year mystery



GETTY IMAGES, NASA

A closer look at the Sun Telescope captures the most detailed shot of a sunspot **p23** **Life under lockdown** Has COVID-19 changed the ways we regard restrictions and rule-breaking? **p26** **Giraffe rescue** How conservationists saved endangered giraffes from flooding **p28**



The gravity of the massive galaxy NGC 1035 (left) is stripping away the contents of its smaller neighbour NGC 1052-DF4 (centre)

It's all NGC 1035's fault. That's what observations made by an international team of researchers using the Hubble Space Telescope have suggested is the cause of a mysterious disturbance in a galaxy, far, far away. They've discovered that NGC 1035 is a massive galaxy that's so big it is tearing its smaller neighbouring galaxy apart piece by piece, starting with its dark matter. The phenomenon is known as 'tidal disruption', but until now has remained hidden from view.

The story started in 2018 when astronomers discovered a galaxy, around 65 million light-years away, unlike any they'd seen before. What made this galaxy, named NGC 1052-DF2, exceptional was that most of its dark matter (the elusive substance known to make up 80 per cent of the Universe's mass) was missing. The finding left the astronomers puzzled, as dark matter plays a key role in the current models of galaxy formation and evolution. Without it, the clouds of primordial gas made up of hydrogen and helium created in the Big Bang would lack the necessary gravitational pull to start collapsing and forming new galaxies.

“The story started in 2018 when astronomers discovered a galaxy, around 65 million light-years away, unlike any they'd seen before”

A year later, another galaxy with missing dark matter (this one named NGC 1052-DF4 and 45 million light-years away) was discovered, proving that NGC 1052-DF2 wasn't unique.

Now, new evidence gathered by Hubble has been used by a team of researchers led by Dr Mireia Montes of the University of New South Wales in Australia, to suggest that NGC 1052-DF4's dark matter is being stripped by the gravitational pull of its massive neighbour NGC 1035. The

smaller galaxy's dark matter is the first thing to be torn away by the larger galaxy as the tidal disruption takes hold, with the stars succumbing at a later stage.

“We used Hubble in two ways to discover that NGC 1052-DF4 is experiencing an interaction,” said Montes. “This includes studying the galaxy's light and the galaxy's distribution of globular clusters.”

Globular clusters are spherical clusters of stars thought to have formed in the episodes of intense star formation that shaped galaxies. Their compact size and luminosity make them easy to observe.

Thanks to Hubble's high-resolution imagery (and with help from the Gran Telescopio Canarias and the IAC80 telescope, both in the Canary Islands), the team could identify NGC 1052-DF4's globular cluster population. This enabled them to construct a 3D picture of what's happening in the galaxy. The alignment of its globular clusters suggests that they're being stripped from their host and that tidal disruption is occurring.

“This discovery reconciles existing knowledge of how galaxies form and evolve with the most favourable cosmological model,” said Montes.



PROFESSIONAL GAMERS

Think all gamers are out of shape? Think again. A survey of 1,400 gamers carried out by Queensland University of Technology found that they're up to 21 per cent more likely to be a healthy weight than the general population, hardly smoke and drink less.

CHEESE LOVERS

A study carried out at Iowa State University based on data from nearly 2,000 UK adults aged 47 to 77, found that those who regularly ate cheese also seemed to experience less cognitive decline.

Good month

Bad month

VIDEO ASSISTANT REFEREES

The VAR needs glasses! After analysing 600,000 tweets made during 129 Premier League games, a team at the Technical University of Munich found that the general mood of comments dropped for 20 minutes following decisions made by VAR.

ALIEN HUNTERS

Don't bank on meeting ET anytime soon. Researchers at the University of Oxford have theorised that the emergence of life on Earth was due to a series of highly unlikely 'evolutionary transitions'. It turns out that we're rather special.



NASA, ALAMY ILLUSTRATIONS: CATHAL DUANE



A newborn's body has to begin functioning independently in the first moments after birth

PEDIATRICS

Scientists close in on brain signal that triggers first breath

Scientists from the University of Virginia School of Medicine have discovered that a mouse's first gasp after birth triggers a signal in the brainstem that activates a critical breathing support system as a baby exits the womb.

Neither mice nor human babies need to breathe in the womb as oxygenated blood is circulated by the mother through the umbilical cord. Amniotic fluid fills the newborn's lungs at birth and is expelled as their lungs inflate with the first breath.

"Birth is traumatic for the newborn, as the baby has to independently take control over various important body functions, including breathing," said Prof Douglas Bayliss, one of the scientists who made the discovery. "We think that activation of this support system at birth provides an extra safety factor for this critical period."

It's hoped a better understanding of this brainstem signalling system

could help prevent brain-damaging and potentially deadly pauses in babies' breathing.

Specifically, researchers found that mice possess a gene that produces a neurotransmitter (a messenger between neurons) immediately after birth. Deactivating this transmitter caused serious breathing problems in mice. This suggests that a problem with the neurotransmitter or guiding gene could contribute to sudden infant death syndrome (SIDS). Also known as cot death, SIDS is the leading cause of infant mortality in Western countries.

"These findings raise the interesting possibility that additional birth-related changes may occur in the control systems for breathing and other critical functions," said Bayliss.

The scientists say that there may be other important factors contributing to SIDS still to discover, though. Plus, it's yet to be seen how insightful this mice study is to human childbirth.

EVOLUTION

A fish out of water: funny bone sheds light on the evolutionary transition from sea to land

The funny bone, or humerus, is known to most of us because of the unique tingling sensation you feel when it's bumped. But thanks to its relative abundance in the fossil record, this bone has also helped scientists trace how vertebrates moved from water to land.

A team of researchers at Harvard University and the University of Cambridge analysed 3D models of 40 fossilised specimens that were thought to be alive during the time of the water-

to-land transition. You might expect the fossil records to show changes in the humerus that preceded emergence onto land, such as animals with limbs suited to crawling in the mud before they ever left the water, but the team showed this is not the case.

"Just looking at the fossils, you can see the shape changing, but by quantifying in 3D, we can use this to understand how the function was changing across the evolutionary transition," said lead

researcher Dr Stephanie Pierce.

As fins evolved into limbs, the humerus became more elongated and twisted to support new needs that arose, thanks to the change in living conditions.

"As the form improved for land movement, it had to trade off other things," said Pierce. "For instance, the shape of the bone in a terrestrial tetrapod is actually a much weaker structure than the fish had originally. But, by creating this unusual shape, the animal had a longer stride length and could move with more ease – all the things that you want if you're walking."

The researchers also found that mid-transition species had an L-shaped humerus, an awkward in-between stage. "The earliest tetrapods essentially lost most of the features that were good for swimming, only gaining a few adaptations that were good for walking. They were in this sort of performance valley," said Pierce. The researchers now plan to delve deeper into what they describe as one of the biggest evolutionary transformations that has ever occurred on Earth, to better understand how vertebrates got on land.



Vertebrates moved onto land around 390 million years ago, which required their fins to evolve into limbs



Caenorhabditis elegans roundworms share many characteristics of human biology, making them useful in scientific research



BIOLOGY

Living in low gravity can alter DNA, study in worms suggests

Living for periods at low gravity may alter your DNA, according to a new study of nematode worms aboard the International Space Station (ISS).

The *Caenorhabditis elegans* worms – animals with a length of 1mm and a life expectancy of two weeks – showed alterations in an estimated 1,000 genes. While most changes were subtle, scientists noticed microgravity had a stronger effect on genes associated with the nervous and immune systems.

“These changes might help explain why the body reacts badly to spaceflight. It also gives us some therapy targets in terms of reducing these health effects, which are currently a major barrier to deep-space exploration,” said the University of Exeter’s Dr Timothy Etheridge, one of the lead researchers on the new project. “Our findings should provide foundations for a better understanding of spaceflight-induced health decline in mammals and, eventually, humans.”

After being hatched on the ISS, the tiny worms were kept in flasks of liquid (containing food) for 4 or 10 days. They were then frozen and examined after their return to Earth using DNA microarray tools, which scan a collection of genes.

Spending long periods in microgravity has previously been shown to drastically alter the human body. Although they dedicate several hours of their day to exercise, astronauts can lose up to 40 per cent of their muscle mass after 180 days on the ISS. This is a significant problem, particularly for future exploration, as it could take a crew 10 months to reach the surface of Mars.

During the acceleration of lift-off and landing, astronauts are also briefly exposed to hypergravity – forces of gravity greater than those found in normal Earth conditions. By placing more worms in a centrifuge, the new study indicated that spending four days in gravity 15

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“These changes might help explain why the body reacts badly to spaceflight. It also gives us some therapy targets in terms of reducing these health effects”

times stronger than that of Earth could alter around 1,360 genes. Similar to microgravity, genes impacting the immune system were most affected.

Fortunately, astronauts are unlikely to spend several days in such levels of hypergravity, unless flying close to objects such as the Sun or sharply accelerating for long periods.



GENETICS

Want to get fit? Follow your nose

A whiff of your gym bag might make you wince, but your nose could be the key to getting fit. New research carried out on mice suggests there's a link between doing exercise and the expression of genes that relate to scent perception.

Scents may hold the key to keeping you going to the gym

In a study by Sachiko Haga-Yamanaka and colleagues at the University of California, Riverside, mice were placed on a running wheel. Some of the mice voluntarily spent more time running on the wheel and the scientists dubbed them “high-runner mice”. The high-runner mice were bred together, and their offspring were watched on the wheel. High runners were chosen again from this second generation and selectively bred, and so on, until the team had established a line of mice that were bred to be high runners.

“Voluntary wheel running (VWR) is an intrinsically motivated and naturally rewarding behaviour [for mice], and even wild mice run on a wheel placed in nature,” wrote the researchers in their paper.

They then compared the high-runner mice to a control group, who hadn't been selectively bred. Looking specifically at a part of the olfactory system called the vomeronasal organ – located in the noses of mice and humans – and its corresponding neurons in the brain, the researchers noticed that there were 132 genes changed in the high runners.

“The olfactory system became genetically differentiated between the high-runner and control lines during the selective breeding process,” said Haga-Yamanaka. “Our results suggest these chemosensory receptors [which were expressed by the altered genes] are important trait locations for the control of voluntary exercise in mice.”

The vomeronasal organ detects pheromones, chemicals produced by animals that end up in the air. This new knowledge could one day form the basis of a scent that motivates you to get fitter.

It's not yet clear if these odours work by increasing the mouse's motivation for exercise, or if it boosts the neurological ‘reward’ it gets when it's running.

“It's not inconceivable that someday we might be able to isolate the chemicals and use them like air fresheners in gyms to make people even more motivated to exercise,” said co-author Theodore Garland Jr. “In other words: spray, sniff, and squat.”

They did what?

Scientists drop messages in bottles into the River Ganges

WHAT DID THEY DO?

Researchers from the University of Exeter and the Zoological Society of London released 25

500ml plastic bottles at various spots along the River Ganges. Originating in the Himalayas, the Ganges flows through India and Bangladesh before reaching the Bay of Bengal in the Indian Ocean. By embedding GPS and satellite tags into the bottles, the researchers were able to track them as they floated and bobbed their way downstream.

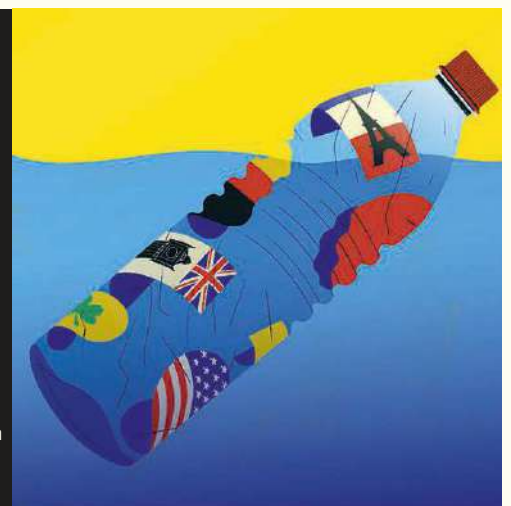
WHY DID THEY DO THAT?

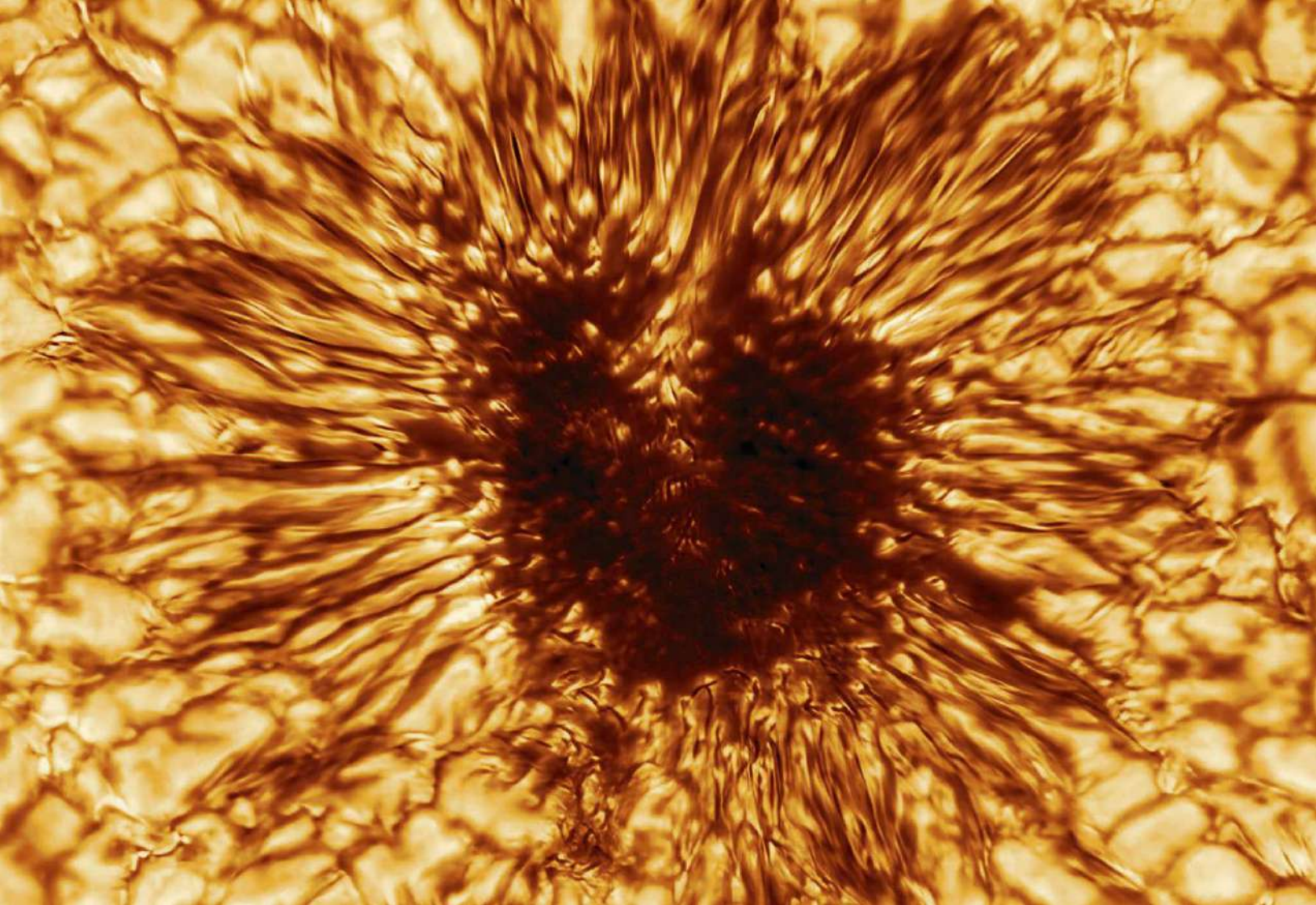
They wanted to observe how far-reaching the impact of plastic pollution is by finding

out how many ecosystems simple rubbish, such as plastic bottles, can interact with.

WHAT DID THEY FIND?

The bottles all followed the same route downstream, with a few getting stuck along the way. Once they reached the estuary, they followed coastal currents, then dispersed and travelled further into the open ocean. One bottle released into the Bay of Bengal at the mouth of the Ganges travelled 2,854km in just 94 days.





ASTRONOMY

Most in-depth sunspot image to date captured by world's largest solar telescope

This stunning image was taken by the Daniel K Inouye Solar Telescope (DKIST) in Maui, Hawaii. It shows the rich, deep-brown heart of a sunspot surrounded by red and orange streaks flaring outwards, giving it the appearance of a psychedelic sunflower.

The Sun has a powerful magnetic field that slowly flips its poles every 11 years. Throughout this cycle, the electromagnetic activity varies across the Sun's surface. Since a new solar cycle began last year, researchers at the National Science Foundation (NSF) in the US have been working to better capture intricate details of sunspots using DKIST, which despite being the world's largest solar

telescope, with an aperture measuring four metres across, is still under construction.

"It's really exciting to see the Sun and sunspots with this extremely high resolution, and see so many details that we've never seen before," said Dr Thomas Rimmele, associate director at the NSF's National Solar Observatory.

"The sunspot image achieves a spatial resolution about 2.5 times higher than ever before and shows magnetic structures as small as 20km on the surface of the Sun," he added.

The sunspot in this image measures approximately 15,000km in diameter – large enough to comfortably fit the planet Earth to inside it.

Sunspots form in areas where the magnetic fields are particularly strong. Their dark appearance is due to the magnetic fields being so strong that they keep the heat within the Sun from emanating to the surface, making them cooler than the areas that surround them. But temperatures considered cold for the Sun are still more than 200 times hotter than room temperature (around 20-22°C) here on Earth.

The streaks radiating outwards from the dark centre of the sunspot are hot and cold gases being redirected by the magnetic field.

While many of the processes that occur within the Sun remain a mystery, we know that these spots and other associated solar events are capable of affecting GPS systems, power grids and satellites here on Earth.

With construction of the DKIST due to be completed in 2021, this preliminary image gives us just a taste of what's to come. Greater insights into the star's behaviour are expected in the run-up to the next solar maximum, which is predicted to occur in mid-2025.

WILDLIFE

How this deadly, rabbit-sized rodent chooses its poison

Researchers uncover how this unique mammal defends itself from predators

As if the idea of a giant rat wasn't weird enough, a group of scientists have discovered that the African crested rat, a rabbit-sized rodent whose fur carries a poison strong enough to fell an elephant, cultivates its toxic coat by chewing on the bark of the poison arrow tree (*Acokanthera schimperi*). While the toxins are still in its mouth, it licks its fur, making it the only mammal known to sequester plant toxins as a chemical defence from predators.

The scientists, which came from the University of Utah, National Museums of Kenya and the Smithsonian Institution, placed the rats in a specially built enclosure, to observe their behaviour. They watched as the critters gnawed on the plants to draw out the toxin, then licked and chewed the poison into specific regions of their fur.

When offered different plant branches, the rats tended to coat themselves with cardenolides (bitter toxins that cause cardiac arrest) found in the poison arrow tree. The animals didn't always interact with the plants when offered, sometimes sniffing and nibbling here and there without coating their fur, perhaps judging how harmful the poison could be with their keen sense of smell.

When threatened or excited, the rats flare their fur, revealing the specialised hairs that contain the poison.

Describing this defence, Dr Sara Weinstein, lead author of the paper and disease ecologist at the University of Utah, said that any animal that attacks the rat will get "a mouthful of these really potent toxins", which can lead to death or sickness. Predators that survive the experience will give the rodents a wide berth in the future.

This defensive behaviour had only been seen in one rat before, but now Weinstein and her colleagues have studied 25 of the rodents, and recorded chewing and/or anointing behaviour in 10 of them. "The patterns we were seeing in many individuals proved it wasn't just a freak occurrence," she said. "We know that this is behaviour that they seem to do consistently."

The team also discovered that the animals were sociable, and would interact with each other when placed in the enclosure. This was a surprise, as the rats were previously thought to be solitary. Future work will investigate both biochemical and behavioural factors of these intriguing creatures. Using DNA sequencing, we could learn how African crested rats (and even their fleas) remain unaffected by this poison. Studying their social structures could reveal new information about the rats' relationships.

African crested rats
anoint specialised hairs
with plant toxins to protect
themselves from predators



STEPHANIE HIGGINS, MARK WITTON

EVOLUTION

Ancient Madagascan bird fossil turns what we know about bird evolutionary anatomy on its head

Fossil shows 68-million-year-old bird had a dinosaur bone structure but a modern face

A new species of bird that lived around 68 million years ago has been discovered on the island of Madagascar, and its unusual beak could give fresh insights into how modern birds evolved.

Discovered from a single, nearly complete skull that was fossilised after it was buried in muddy debris, *Falcatakely* is a crow-sized bird with a scythe-shaped beak. This is not at all unusual in modern birds, and is similar to the beaks of hornbills and toucans. However, there's a gap of tens of millions of years between these species evolving.

"What is so amazing is that these lineages converged on this same basic anatomy, despite being very distantly related," said Dr Ryan Felice, lecturer in human anatomy at University College London and one of the study's authors. In fact, this is the first time such a beak shape has ever been found on a bird from the Mesozoic – the era that contains the Cretaceous, Jurassic and Triassic periods.

Looking underneath the skin of *Falcatakely* reveals another unusual feature. Though its face may have the appearance of a modern bird, its underlying bone structure is much more like a dinosaur's.

Modern birds have a beak made mostly of one large bone, called the premaxilla. Ancient birds, like *Archaeopteryx*, instead had two, with a small premaxilla and a large maxilla.

So, *Falcatakely* developed a modern face shape without a modern facial structure. "*Falcatakely* might generally resemble any number of modern birds with the skin and beak in place, however, it is the underlying skeletal structure of the face that turns what we know about bird evolutionary anatomy on its head," said Prof Patrick O'Connor, an anatomist at Ohio University.

The researchers haven't been able to study the skull directly. Bird fossils are rare, because their skeletons are so delicate that they are usually destroyed rather than fossilised. The specimen is so fragile that they couldn't even remove it from the rock. Instead, they used high-resolution micro-computed tomography to scan the fossil, which they then used to digitally reconstruct it.

"The discovery of *Falcatakely* underscores that much of the deep history of the Earth is still shrouded in mystery," added O'Connor.

"The discovery of *Falcatakely* underscores that much of the deep history of the Earth is still shrouded in mystery"



Falcatakely had a similar beak to modern hornbills and toucans



PROF JOHN DRURY
Social psychologist

Horizons

Has our behaviour changed during the course of the pandemic?

There's no doubt that the introduction of new rules and regulations has had an impact on our actions over the past year. But what are the factors at play when it comes to getting the public to protect each other?

WHAT ARE SOME OF THE HEADLINE POINTS THAT HAVE AFFECTED PUBLIC BEHAVIOUR?

From the beginning there's been consistent evidence of some of the factors that matter. One of the things is the belief in the extent to which the coronavirus measures are effective. Another one is the extent to which there is a threat. The greater the R number [the R number is how many people one infected person will pass the disease to] then the more adherence there is.

But things like your sense of solidarity are also really important. People are doing it for others, not necessarily for themselves. The sense of fairness or justice. That's come up with the new tiers, but in fact it's always been a factor.

And then linking these, is confidence in what the government is doing. There was a very good panel survey carried out by University College London which found that confidence in the government was the major predictor of adherence of many of the behaviours we were asked to engage in.

WHAT ROLE DOES THE SENSE OF PERSONAL REWARD PLAY?

For most people, there's not a lot in it. It's a minority of people, 1 in 100, that

might suffer fatalities. We are doing it for others. This is a debate to be had about the role of sacrifice.

There was a very good review published by my colleagues Prof Susan Michie and Prof Robert West, which looked at whether there was any evidence for fatigue over time, and they decided that there wasn't. Look at other kinds of events where people make a sacrifice, like marathon running and religious festivals. These are physical endurance events. And people will do these things for a greater cause.

WHAT SORT OF EFFECT DO YOU THINK A PUNISHMENT, SUCH AS A FINE, HAS ON BEHAVIOUR?

The question of punishment or coercion more generally in public health measures has been looked at in other contexts. I was involved in some research looking at mass decontamination when there's a chemical incident. That requires a sacrifice in the form of having to take your clothes off and go through a shower in public space. So a behaviour with a high personal cost. And when people were coerced into it, or were attempted to be coerced into it by being shouted at and threatened, then engagement went

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“Things like your sense of solidarity are really important. People are doing it for others, not necessarily for themselves”

GETTY IMAGES





down. People did engage when there was communication, when there was concern and care about people's needs. Punishment was therefore counterproductive because it led to people resisting the thing they're being asked to do. The general point is that punishment or coercion affects the relationship, so the relationship becomes not about public health, but about our rights and that we're being bullied.

If you look at it in terms of COVID-19, one of the early studies carried out at the London School of Economics found that the threat of punishment was an inferior predictor to people's adherence to the rules than the law, because the law was being used quite early on. It was in use since March. It was a poor predictor.

If you look at one behaviour, self-isolation, it has very poor levels of adherence at 10 or 20 per cent, those are the kind of figures. Now you've got punishments for failing to self-isolate. But if you look at the data on the process, why is it that people are not self-isolating enough, for the full 14 days? There are psychological factors at play, but it's not wilfulness – it's things like not knowing the rules, things that your peers are doing. Then you've got who they are. There are

certain demographics. People who haven't got financial support, or social support. To bring in punishment when you know non-adherence is not wilfulness – that misunderstands what's going on there.

WHAT ROLE IS THE VACCINE LIKELY TO PLAY WHEN IT BECOMES AVAILABLE?

I used to say when I talked to people about the role of psychology and behaviour in the pandemic that until we've got a vaccine, it's all about behaviour. It's about distancing, washing hands, and self-isolation.

But actually, when you've got a vaccine, it's still about psychology because people have got to believe in the vaccine. They've got to do the behaviour of getting the vaccine. And vaccine hesitancy is a big thing, right? Some of the survey data I've been looking at recently shows that vaccine confidence has actually been going down, just at the time when we need it to be going up.

There needs to be a lot of work to reassure people, because vaccine hesitancy is actually a small majority of people. It's not the committed minority, but a very large number of people who are hesitant. There needs to be information that will make people believe that the vaccine

is safe and effective, so these are psychological things.

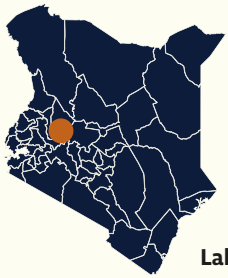
WHAT SORT OF LONG-TERM IMPACTS COULD THE PANDEMIC HAVE ON OUR PSYCHOLOGY?

My current research is on mutual aid groups [teams of volunteers that were set up to help local people out, during the pandemic]. These groups have been able to meet the needs that the authorities haven't been able to. As we said, self-isolation has been a problem as people are not isolating enough when they need to isolate. They need financial support. They need social support. And that means someone getting their shopping. It means getting their prescriptions. It means walking their dog. It means giving them emotional support, lots of these things. These mutual aid groups were set up to help provide that.

Now, if you look at the development of these groups, certainly there was a surge in activity in the early months and then they declined. You look at them now, and many of them are still going and some are having conversations about how they take it forward after COVID. Are they still going to be there? They are networks, but they're also alternative structures. They're alternative ways of doing things, or even alternative ways of doing politics. And that's how some people think of them now. Some of them are people who have been involved in groups and volunteering before, but many of them are new people seeing things in a new way. So it's quite hard work for them and there's a risk for people involved in those groups of stress and burnout. But it is also quite an exciting prospect for the future.

PROF JOHN DRURY

John is a social psychologist at the University of Sussex and is member of Independent SAGE. Interviewed by BBC Science Focus commissioning editor Jason Goodyer.



Lake Baringo, Kenya



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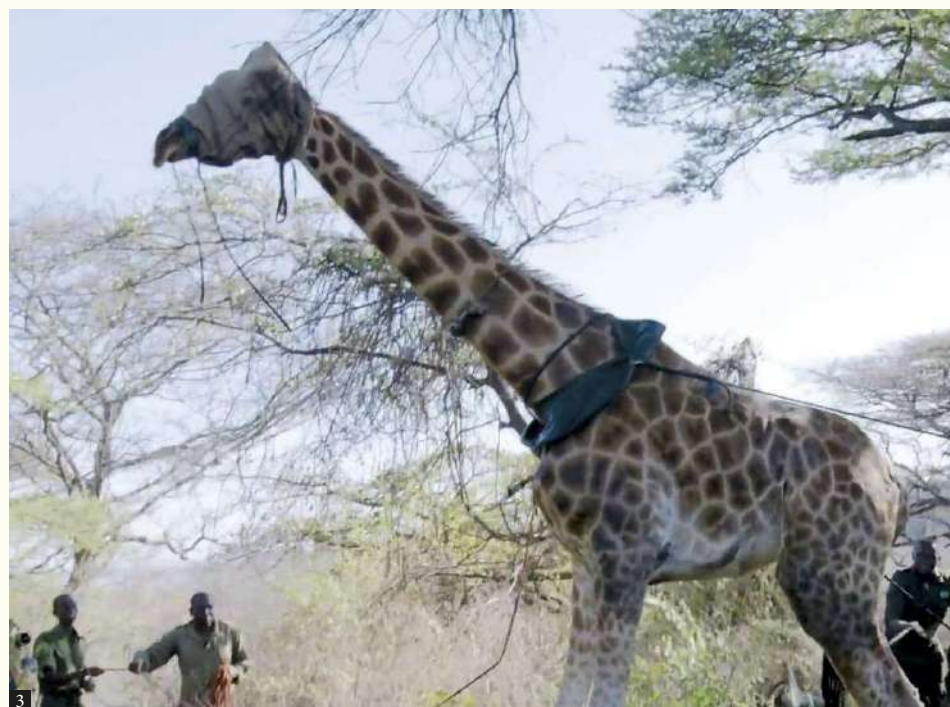


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WILDLIFE

Kenyan conservationists stage daring rescue of endangered Rothchild's giraffes

The Kenya Wildlife Service and the charity Save Giraffes Now have rescued two of eight Rothchild's giraffes that became trapped on a small island in Kenya's Lake Baringo, following a bout of flooding caused by heavy rainfall. They plan to save the remaining animals over the next few months.



SAVE GIRAFFES NOW X4

3



1. The giraffes were originally homed on the island in 2011, in order to protect them from poachers. There are thought to be fewer than 2,000 Rothchild's giraffes left in the wild, making them one of the most endangered giraffe subspecies.

2. The animals were sedated and blindfolded to calm them down, before being floated to safety on a raft that was

specifically constructed by locals. This female, named Asiwa, was the first passenger.

3. Rothschild's are one of the largest of the nine subspecies of giraffe and can reach heights of nearly six metres and weigh more than 1,000kg.

4. The team celebrates after completing the almost 6km trip to Asiwa's new home in the 4,400-acre Ruko Giraffe Sanctuary.





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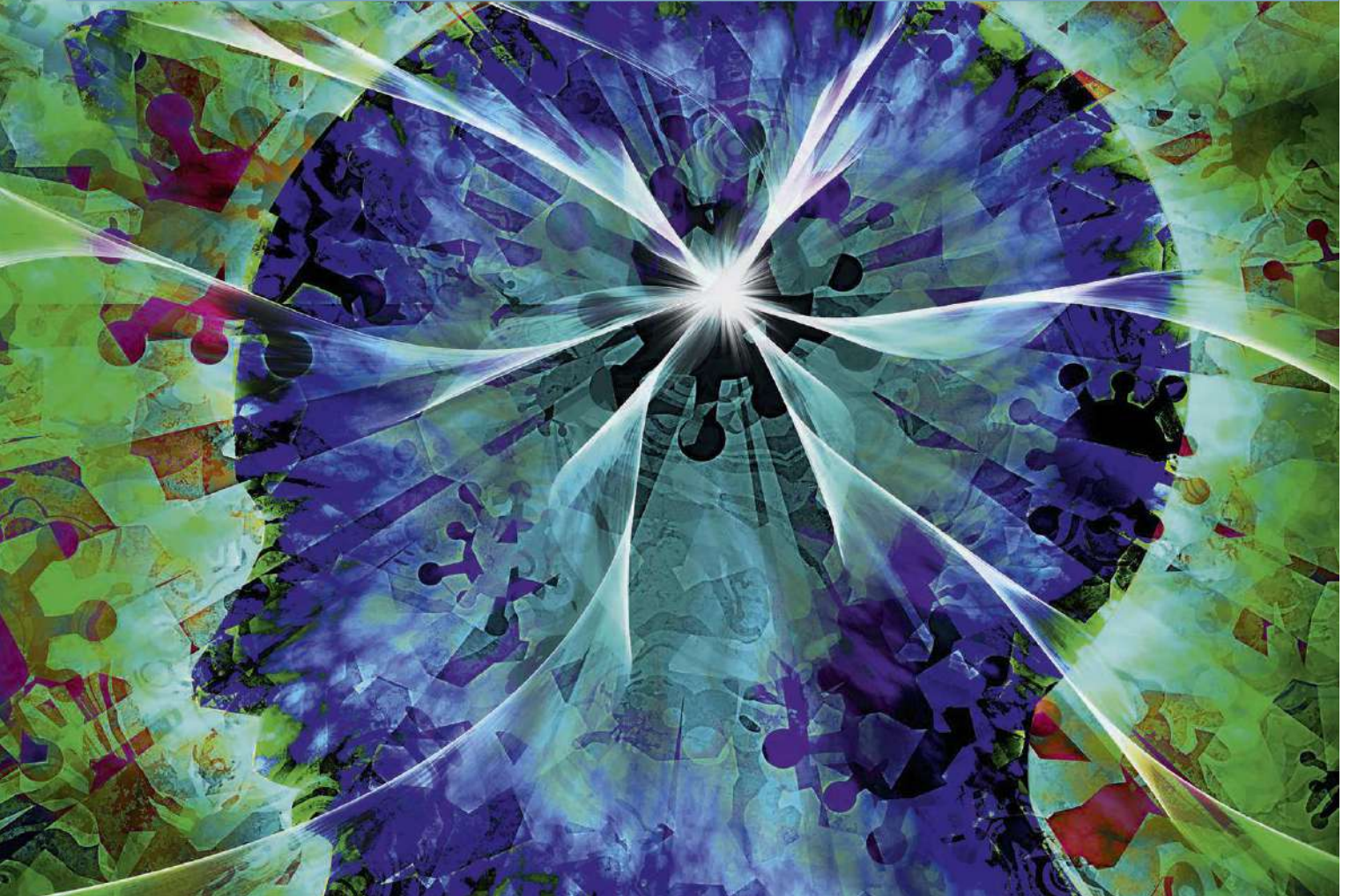
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REALITY CHECK

SCIENCE BEHIND THE HEADLINES

COVID-19 and the brain | Vaccine fears | Online junk food ads ban



ANALYSIS

COVID-19 AND THE BRAIN: DOES THE VIRUS CAUSE PSYCHIATRIC PROBLEMS?

COVID-19 patients face a higher risk of psychiatric disorders. Is that because of the social impacts of the pandemic or is the virus finding its way into our brains?

“Out of the 62,000 people who were diagnosed with COVID-19 in the study’s cohort, one in five went on to receive a diagnosis for depression, anxiety or insomnia”



Visit the BBC's Reality Check website at bit.ly/reality_check_ or follow them on Twitter @BBCRealityCheck

The lockdown and social-distancing measures applied around the world to manage the pandemic have led to high rates of mental health problems, including depression, anxiety and post-traumatic stress disorder (PTSD). This makes sense: we know that social isolation can have negative psychological consequences, as can economic uncertainty, rising unemployment and widespread financial struggles.

Aside from the social and economic effects of the pandemic, could catching COVID-19 lead to mental health problems? And if so, would it mean that the virus was finding its way into our brains?

Using data from 69 million individuals in America, researchers at the University of Oxford compared people diagnosed with COVID-19 to those suffering from different health problems, such as the flu or another respiratory infection. This approach enabled them to rule out the possibility of any findings being attributed to the impact of being seriously ill or being admitted to hospital.

“We know when people have been ill [with a non-COVID-related illness], they’re more likely to develop mental health problems than if they had not been ill in the first place,” explains Paul Harrison, a professor of psychiatry at the University of Oxford who was involved in the research and the lead author of the study that came out of it. “We wanted to find out if there was something specific about COVID-19 that makes that risk greater than it would have been if you’ve been ill for some other reason. And we did find that was the case.”

Out of the 62,000 people who were diagnosed with COVID-19 in the study’s cohort, one in five went on to receive a diagnosis for depression, anxiety or insomnia following their illness. Some of the cohort had previously had a psychiatric diagnosis for one of these conditions, but 1 in 20 patients was experiencing mental health problems for the first time in their life following infection with the new coronavirus.

Those with COVID-19 were twice as likely to get one of these psychiatric diagnoses compared to the other patients. Being hospitalised with COVID-19 put all patients at higher risk, but even a mild form of the illness was associated with developing mental health problems in the three months following diagnosis.

The researchers did notice a significant difference in the mental health impacts of having any health problems after 1 April 2020, when America’s coronavirus death toll surpassed that of the Vietnam War. Having any illness after that date came with a higher risk of being diagnosed with a psychiatric condition. The researchers attribute this to contextual factors, such as a fear of being admitted to hospital and catching COVID-19, or knowing health services were already overwhelmed.

But even if there is a link between COVID-19 and an increased risk of psychiatric disorders, what mechanism could be behind it?

“There are certainly viruses that infect our brains and cause very serious problems, even death. But equally, there are lots of common viruses where that doesn’t seem to happen. The straight answer is we just don’t know yet which COVID-19 could be,” says Harrison. ➤

BELOW COVID-19 can have physical and mental effects on the people who catch it



► Previous studies have sought to identify how other viruses can get into the brain and the body's central nervous system. Patients hospitalised with two other coronaviruses, SARS and MERS, were found to have almost a one in three chance of developing PTSD, and 15 per cent of patients had depression and/or anxiety a year after their illness. Harrison says that there could be many non-biological reasons for this.

"Your life has been affected; you may have lost your job, had problems paying the rent, you might have been worried that you're not going to get better," he says. "In addition, there may be biological mechanisms. Because you've gotten ill, that may have triggered an immune reaction in your body, for example. We know that the immune response can sometimes get into the brain and affect the way we feel and the way our brains function."

Several viruses are known to infect the central nervous system, affecting the brain and spinal cord in the process. These include the virus that causes influenza, the measles virus and the human immunodeficiency virus (HIV), as well as coronaviruses.

While studies looking at the effects of the COVID-19 coronavirus on the central nervous system are still ongoing, initial findings from the C-MORE (Capturing Multi-Organ Effects of COVID-19) study have used magnetic resonance imaging to detect tissue changes in parts of the brain. Another study, by scientists at Temple University, in Pennsylvania, has shown how the spike proteins found on the coronavirus can inflame cells on a model of the blood-brain barrier, causing the barrier to become 'leaky' and potentially disrupting the brain's delicate neural networks.

"It's easy to speculate that COVID-19 might be doing some things, particularly in our brains, to cause depression and anxiety, but that's just a hypothesis," says Harrison. "We need to do other kinds of studies, which are now underway, to see if that's true. Of course, if it is true, then we need to think of treatments that could either prevent that happening in the first place, or could help patients deal with it if it does happen."

by AMY BARRETT

Amy is the editorial assistant at BBC Science Focus.



REVIEW

CORONAVIRUS VACCINE: IS IT SAFE?

Alongside wild conspiracy theories, many people have raised doubts over approved COVID-19 vaccines. Is their dose of scepticism well-founded?

Within a year of COVID-19 appearing in the UK, the seemingly unthinkable has happened: vaccines for it have started being administered to people across the country.

The first of the vaccines, developed by Pfizer/BioNTech, was approved by the Medicines and Healthcare products Regulatory Agency (MHRA) as safe to use on 2 December 2020. This assessment was made, according to the MHRA's chief executive Dr June Raine, after "a rigorous scientific



assessment of all the available evidence of quality, safety and effectiveness.”

For some people, however, the news was too good to be true. A YouGov survey indicated that one in five British people (and 42 per cent of those aged between 25-49) say they’re unlikely to take the vaccine. The majority of those surveyed cite safety concerns as the reason for their reluctance.

COULD THE CORONAVIRUS VACCINE HAVE HIDDEN LONG-TERM EFFECTS?

With all coronavirus vaccines having been trialled for less than a year at this point, it’s true that their long-term effects are not completely understood. Yet scientists say it’s unfair to compare the vaccines to the likes of thalidomide. First sold in the UK in 1958, thalidomide – a drug marketed as a sedative and treatment for morning sickness – was found to cause major birth defects when taken by pregnant women, three years after it appeared on the market.

First, unlike thalidomide, coronavirus vaccines are being tested with special consideration for pregnant women. For instance, while approved for most of the UK population on 2 December 2020, the Pfizer vaccine wasn’t given the green light for

ABOVE The UK’s programme of COVID-19 vaccinations began in December 2020

expectant mothers or those who are breastfeeding. This, the MHRA says, is now simply a “standard measure” for new vaccines that haven’t been specifically tested on that group.

Experts also say long-term side effects for the general population are extremely low. “You would typically see the adverse effect of vaccines within the first couple of months. But many vaccines have been tested since June 2020 and we’ve seen no evidence of this so far,” says Dr Jeremy Rossman, lecturer in virology at the University of Kent.

“Is there a chance that there’s going to be some sort of effect that we’ll see months or two years down the line? Sure. It’s possible. But it would probably only impact an extraordinarily low number of people.”

Rossman instead points to the higher risk of developing so-called ‘long COVID’. Using data from the COVID-19 symptom tracker app, it’s estimated between 1 and 10 per cent of people can still suffer from symptoms 10 to 12 weeks after their infection. “And in many cases, people have symptoms that can last six months or more,” Rossman says. “We still don’t really understand long COVID and how dangerous it is.”

WHY DOES THE VACCINE HAVE TO BE INJECTED?

While some current vaccines are administered through a nasal spray, coronavirus vaccines will initially be given through an injection in the arm. According to Rossman, this is simply because such vaccines are faster to develop, test and manufacture.

Future coronavirus vaccines could be delivered through the nose, however. In fact, institutions such as Imperial College London have begun trials to assess the safety and effectiveness of several vaccines, including the Oxford/AstraZeneca one, via a nasal spray. And many scientists predict this could prove even more effective than an injection.

“There are certainly good arguments for delivering a vaccine’s payload directly to the upper respiratory tract, like modern flu vaccines,” says Dr David Matthews, a virologist from the University of Bristol. “[A vaccine delivery via the nose] will raise an immune response at what’s called the mucosal surfaces – the surfaces of the nose, mouth and the back of the throat. That’s where you really want a strong and effective immune response if you’re going to beat off a respiratory virus. And, 🍌



❖ crucially, a nasal spray is going to require less training to administer.”

WHAT ARE THE CHANCES OF SOMEONE HAVING AN ALLERGIC REACTION TO THE VACCINE?

Very small. Severe allergic reactions to vaccines are extremely rare, approximately one per million vaccine doses, according to research published in the *Journal Of Allergy And Clinical Immunology*. You have a similar chance of an allergic reaction to anything you put in your body, such as a new food.

Those with a significant history of such reactions (people who are required to carry an adrenaline pen at all times) should check with a healthcare professional before receiving an injection. This is the same advice given to those taking the seasonal flu vaccine.

“This is why, even though the risk is tiny, the vaccine is administered in some sort of healthcare-providing setting,” says Rossman. “Because you’re not going to get the jab and have a reaction six hours later; you’ll have it immediately and get care immediately. But the risk really is extraordinarily low.”

IS THERE A RISK, HOWEVER SMALL, THAT THE VACCINE WILL ACCIDENTALLY GIVE YOU COVID?

No, there’s no evidence that any approved coronavirus vaccine may inadvertently infect somebody with the virus.

It’s true that many past and current vaccines are manufactured by inserting a dead or inactive version of a virus into the body. But these have been shown to effectively and safely protect humans from diseases. The inactive rabies vaccine, for instance, is received by more than 15 million people each year, according to the World Health Organization.

But the Oxford/AstraZeneca and Pfizer/BioNTech vaccines aren’t produced by killing or deactivating the virus. “They only contain tiny instructions about how to build a tiny part of the virus, not the virus itself. So, there’s absolutely no chance of getting COVID from them,” says Rossman.

—
by **THOMAS LING**
*Thomas is the staff writer at
BBC Science Focus.*

COMMENT

ONLINE JUNK FOOD ADS: COULD A BAN CUT OBESITY?

The UK government has proposed a ban on internet ads for junk food. Could it improve the nation’s health?

On 10 November 2020, the UK government launched a consultation for a total ban on online adverts for ‘junk’ food. The proposed rules, following on from a broader anti-obesity strategy published earlier in the year, surprised many for being far tougher than expected. All of this sound and fury, after years of relative inaction, was thought to have resulted from Prime Minister Boris Johnson experiencing a Damascene conversion after he caught COVID-19. He blamed the severity of his symptoms on his elevated weight.

Obesity is indeed one of the biggest public health crises the UK faces, with almost two-thirds of adults either overweight or living with obesity. Crucially, one-third of children leave primary school overweight or with obesity, making them more likely to become adults carrying excess weight.

What the pandemic has crystallised for many, including our PM, is that living with obesity increases your risk of a number of different diseases, infectious or otherwise. Hence this far-reaching proposed ban on all online adverts promoting ‘junk’ food high in fat, sugar and salt (HFSS), with the explicit aim of helping protect children from developing long-term unhealthy eating habits.

So what is the evidence that such an intervention would be effective? Well, in October 2020, my colleagues from the Centre for Diet and Activity Research (CEDAR) at the University of Cambridge, estimated that banning unhealthy food advertising on television before the 9pm watershed meant that children in the UK would see, on average, 1.5 fewer HFSS advertisements per day. They calculated that removing these had the potential to reduce the number of UK children with obesity by 40,000 and those who are overweight by a further 80,000. This research however, only examined TV adverts and as anyone with teenaged (or younger) offspring will know, they hardly watch any linear TV. Most children today stream much of their content online, where it’s estimated that 59 per cent of food and drink adverts are for HFSS products. I’m actually surprised that the number isn’t higher. When was the

“Children, if left to their own devices, are likely to seek out the foods that are high in calorie density, like fat and sugar”

last time you saw a food advert (online or otherwise) for broccoli, or cabbage, or beef, or tofu? Instead, the majority of ads will be for major restaurant chains and for pre-packaged foods, with the total size of the online HFSS food and drink advertising market estimated at around £438m. In addition, accessing content online also renders the concept of a ‘watershed’ moot, thus the proposed banning of all such online adverts.

Unsurprisingly, many big beasts in the food industry are pushing back hard on this proposal. A number of manufacturers and brands, including Mars and Kellogg’s, have written to the government seeking more time to respond to the consultation, arguing that the plans would disproportionately hit small- and medium-sized business. They cite, as an example of this, a hypothetical local wedding cake business, potentially being unable to share product details on its Instagram account. If true, this would be a fair point. I’m certain, however, that the regulators would be able to differentiate between a multinational corporation advertising burgers or pizzas and ‘Wilma’s Wonder Wedding Cakes’ from the local high street promoting their tiered sponge confectionery.

Here’s the bottom line: children, if left to their own devices (pun fully intended), are likely to seek out the foods that are high in calorie density (fat and sugar). This is an evolutionarily conserved trait to ensure a small and helpless mammal grows as quickly as possible to reduce its chances of becoming tiger food. We, as a society, are therefore duty-bound to protect our children, whatever size they are, from the choices they are hardwired to make in this current food environment. Crucially, research suggests that such an online advert ban will be most beneficial to children whose parents earn the least (and are therefore at increased risk of obesity and other diet-related illnesses), compared to those who earn the most, thus additionally playing a role in reducing socioeconomic health inequalities.

As with most things, the devil is, of course, in the detail. What will fall under the HFSS umbrella? At the time of writing, this was still not clear. Also,

what would constitute a ‘successful’ intervention? We must resist eye-catching, but ultimately crude, short-term outcomes such as ‘did it single-handedly reduce obesity?’, that sets the intervention up for perceived failure. What will be required is high-quality independent evaluation that should measure multiple health and societal outcomes. This will take time and require patience – a trait lacking in most humans.

The causes of obesity are complex, encompassing a myriad of interacting biological, environmental and socioeconomic factors. Thus, a comprehensive approach is needed to address all the drivers that influence health and weight, including a non-hysterical and sober discussion of food advertising that targets children. **SF**

by **DR GILES YEO**



Giles is a geneticist at the University of Cambridge. He is a presenter on Trust Me, I'm A Doctor and the author of Gene Eating: The Story Of Human Appetite (£14.99, Orion Spring).

BELOW A proposal by the UK government could put an end to online advertisements for junk food



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Take your smart home to the next level p42

INNOVATIONS

PREPARE YOURSELF FOR TOMORROW



Colin Buchan, head chef of restaurant 1880, had the pleasure of serving up Eat Just's GOOD Meat cultured chicken

BLUENALU

With overfishing putting the ocean's fish stocks and future at risk, there's a clear argument for cultivated seafood. BlueNalu is working on the first fried fish alternative that's been grown in bioreactor.

**PERFECT DAY**

Promising to "change the process, not the food", Perfect Day Food could be onto something with its dairy products. After all, a decent cheese has long been the holy grail for those who decide to go vegan.

**MOSA MEATS**

Mosa Meats cooked the world's first cell-cultured burger back in 2013, which cost around €250,000 to make (funded by Google's Sergey Brin). Now Mosa Meats says it can grow burgers for about €9 a pop.



FOOD

Diners enjoy world's first restaurant meal made from lab-grown meat

Singapore-based restaurant served up real chicken that didn't require the slaughter of any animals, paving the way for new ideas about how we eat meat

By the time you read this, a group of friends at a restaurant in Singapore will have shared a three-course meaty meal, which was made without slaughtering any animals – potentially a landmark moment for an industry coming to terms with its impact on the environment.

The cultured chicken used for the meal was grown in bioreactors, similar to the kind used to make beer or yoghurt, by US start-up Eat Just. The meat, branded as GOOD Meat, was approved for sale by the Singapore Food Standards Agency in December, and is the world's first cultured meat product to be sold commercially. The meals were served up by a restaurant called 1880, which aims to stir up debate around what we eat.

Generally speaking, cultured meat is made by harvesting stem cells from muscle tissue, before placing them in a substance that has everything the cells need to grow and proliferate. At a certain point, these are encouraged to differentiate and they mostly become

muscle cells, which merge to form primitive muscle fibres. Eventually this is ground up and shaped into a burger, or in the case of the Singapore restaurant, a "chicken bite".

The lab-cultured meat will mostly be used to make chicken nuggets, which might be considered a bit of a low bar. But the demand for meat analogues, which more closely resemble the food with which we are familiar, is clearly on the increase, with companies such as Beyond Meat and Impossible Foods selling their meat-free burgers in fast food franchises and supermarkets alike.

Why eat cultured meat? Well, estimates vary, but livestock generates around 15 per cent of the planet's CO₂ emissions and there are concerns that the farming industry's use of antibiotics in livestock is contributing to the rapid rise of diseases resistant to the medicines. If cultured meat can scale up its production, while producing lower levels of pollutants than farming, it could mitigate the impact of a growing global population that's demanding more meat.

Eat Just isn't alone. There are dozens of companies racing to mass-produce cell-cultivated chicken, seafood, pork and beef. Here's hoping we get to try some out in 2021.

"THE CULTURED CHICKEN IS GROWN IN BIOREACTORS, SIMILAR TO THE KIND USED TO MAKE BEER"

Eat Just is concentrating on lab-grown chicken at the moment, but there is clearly a demand for other types of meat



BUYER'S GUIDE

How to **AUTOMATE YOUR SMART HOME**

Doing things for yourself is so 2020. Jennifer Pattison Tuohy picks the best products to make your home work for you...

Our homes are evolving. Smart speakers, like Amazon's Echo or Google's Nest devices, are flying off the shelves and into the hearts of our homes. Our appetite for digital home assistants didn't even seem to slow during the pandemic, with 30 million sold worldwide over the summer of 2020. So if you've invited a virtual butler into your home, here's our pick of what we think are the key products you should install if you are looking to make the leap from a smart speaker to a smart home. Once you have these in place, you can start stringing them together and automating much of your home life.



Best Smart Security System – Abode Smart Security Kit

FROM £299.99 | **BUY FROM** GOABODE.CO.UK | **WORKS WITH** AMAZON ALEXA, GOOGLE HOME, APPLE HOMEKIT

A smart security system protects your home, thanks to wireless sensors and cameras that you can monitor from your smartphone. But the sensors that detect when a door opens, or if there's

motion in your house, can also tie in to other smart devices, such as lights, locks and thermostats, telling them when to turn off, unlock or change the temperature.

Our top pick is Abode, as it offers a solid DIY security system with expandable smart home capabilities. Abode's monthly fee starts at just over £3 a month, but we like the Monitored Immediate plan at £13.99 a month, as it gets you professional monitoring, cloud storage for a video feed, and smart features such as geofencing of the alarm (tracking your location by your phone) so you don't have to worry about triggering it accidentally.

Best Mesh Wi-Fi Router Google Nest Wi-Fi

FROM £129 | **BUY FROM** STORE.GOOGLE.COM | **WORKS WITH** GOOGLE HOME

A mesh Wi-Fi router spreads Wi-Fi signal throughout your home, regardless of walls or inconvenient layouts. It consists of 'hubs' you plug in around the house to demolish dead zones. While not the fastest or most advanced mesh system available, Google Nest Wi-Fi fits excellently into a smart

home for two reasons: it works as a 'hub' for some connected gadgets, and doubles as a smart speaker. Each 'point' is also a Google Assistant voice speaker, spreading Wi-Fi and voice control all over your home. Plus, it's simple to set up and run. You manage it from Google Home's app on your smartphone, and there are built-in parental controls that give you the ability to shut down connectivity to your kids' devices with just a word – ideal for getting them to the dinner table on time.





Best Smart Security Camera

Arlo cameras

FROM £125 | **BUY FROM** [ARLO.COM](https://www.arlo.com) | **WORKS WITH** AMAZON ALEXA, GOOGLE HOME, APPLE HOMEKIT

A smart security camera is an easy way to keep an eye on your home when you're away. They're easy to set up as they use Wi-Fi to send you footage, so no need to run wires through your walls. There are lots of good ones out there, but our top pick is Arlo's system. The small, battery-powered cameras can be installed anywhere, and can be hooked up to power if you don't want to worry about charging them. They have a wide range of price points and can record up to 4K. They're also smart enough to distinguish between people, animals, vehicles and packages, so you don't get inundated with alerts.



Best Robot Vacuum Cleaner

Roomba i3+

FROM \$399 | **BUY FROM** [IROBOT.CO.UK](https://www.irobot.co.uk) | **WORKS WITH** AMAZON ALEXA, GOOGLE HOME

The smart home should be about robots doing everything for you, so you don't have to lift a finger. Sadly, we're a long way from that reality, but in the meantime, there are robot vacuums. More affordable, more intelligent, and better at vacuuming than ever before, a robot vacuum will help

keep your house clean – yes, even under the settee. Our favourite is iRobot's Roomba i3+, the newest model from the oldest smart vacuum manufacturer. We like it for its combination of affordability and self-emptying capabilities – it has its own external bin it returns to to suck out the debris when its on-board bin is full.

The i3 will be available in the UK later this year, but if you can't wait, then the pricier i7+ is an excellent option. The i7+ can do smart things like just clean the kitchen, thanks to smart maps you control in the app. Both bots can be controlled by voice using Alexa or Google, so you can ask it to clean, pause, or go home with just a few words.

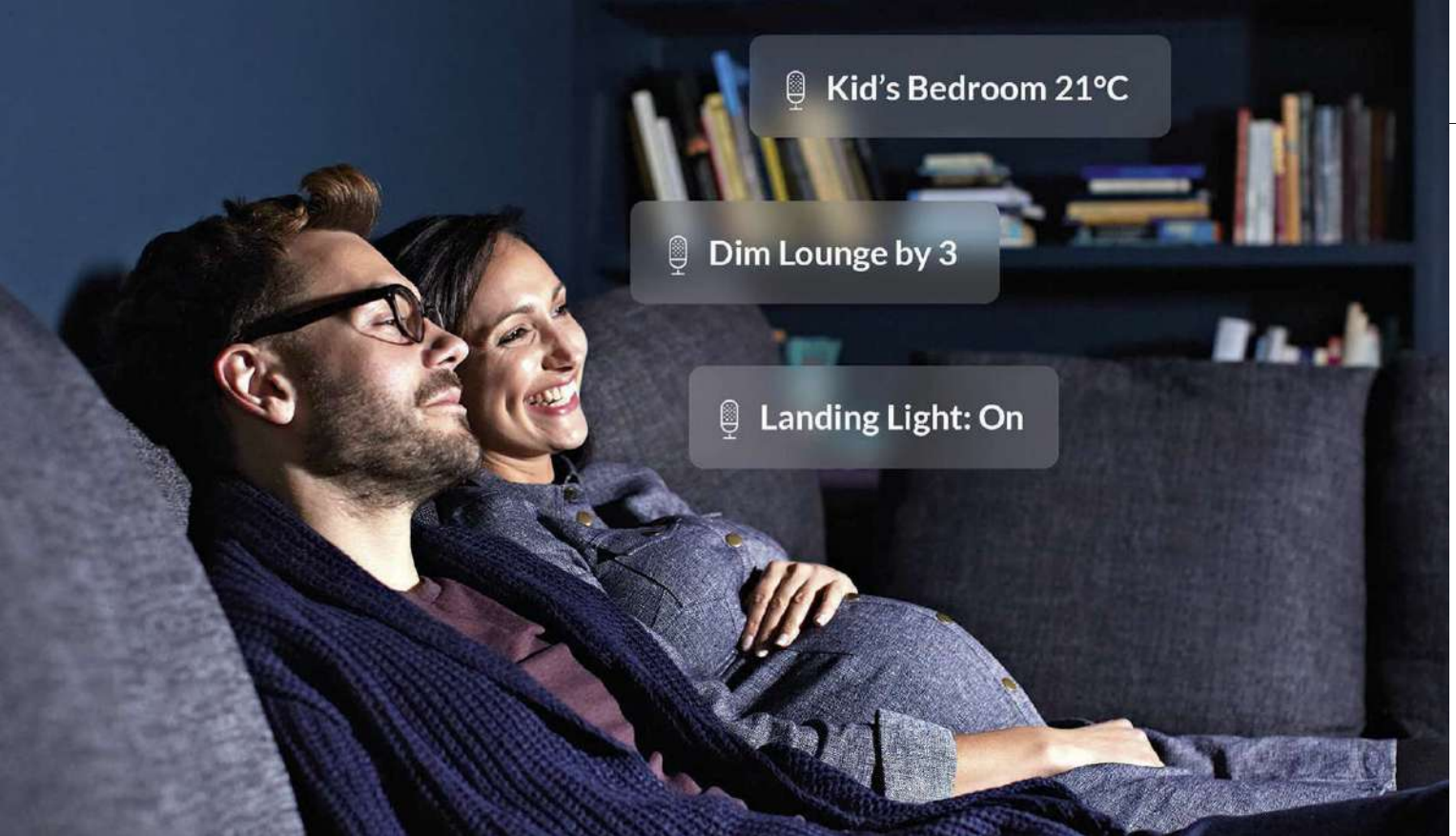
Best Smart Thermostat

Nest Learning thermostat

£219 | **BUY FROM** [STORE.GOOGLE.COM](https://store.google.com) | **WORKS WITH** AMAZON ALEXA, GOOGLE ASSISTANT

The Nest Learning thermostat is the best out there, and now controls your hot water too. While there are cheaper options, none are as smart or look as good. The Nest uses AI to recognise your patterns, based on your adjustments, presence and other factors to continually adapt a schedule that will keep you comfortable and save you energy.





Best Smart Lighting

Philips Hue, Lightwave

PHILIPS HUE FROM £48 | **BUY FROM** [PHILIPS-HUE.COM](https://philips-hue.com) | **WORKS WITH** AMAZON ALEXA, GOOGLE HOME, APPLE HOMEKIT
LIGHTWAVE FROM £185 | **BUY FROM** [LIGHTWAVERF.COM](https://lightwave.co.uk) | **WORKS WITH** AMAZON ALEXA, GOOGLE HOME, APPLE HOMEKIT

Smart lighting is the poster child of the smart home. It's so easy, fun and genuinely useful. Have your lights turn on when you open the front door, come on gradually in the morning as a natural alarm clock, or turn on and off randomly when you're away to make it look like someone's home. These are just a few of the tricks a smart lighting system can pull off, but choosing the right product can be overwhelming.

There are two main routes into smart lights: smart switches that control all the lights on a circuit, or smart bulbs which replace existing bulbs. Both give you wireless control from your phone or via a voice assistant. Our pick for switches (which need to be hardwired) is Lightwave's line, which has compatibility with Alexa, Google and

HomeKit. It uses Lightwave's proprietary wireless protocol (via a hub) rather than relying on your home Wi-Fi, which means it responds speedily to commands – essential with smart lighting, as if you have to wait for a few seconds for it to turn on, you'll find yourself reaching for a switch.

For smart bulbs, the Philips Hue line is the best and most reliable option – it's also affordable now, with a starter kit for just £48. This expandable smart lighting system has bulbs and fixtures for every scenario, and includes wireless switches for physical control when you want it, and motion sensors that adjust the lighting based on time of day. Hue bulbs also offer the option of a dizzying array of colours, if you want to add a unique ambience to your home.

Best Smart Display

Google Nest Hub Max

£219 | **BUY FROM** [STORE.GOOGLE.COM](https://store.google.com) | **WORKS WITH** GOOGLE ASSISTANT

A smart display, which is a smart speaker with a touchscreen attached, adds another level of interaction with a voice assistant, and doubles up as a control panel for connected devices. Check out who or what is rifling through the bins on your security camera footage, use it as a video intercom with a doorbell camera, tap to turn on lights in another room or adjust your thermostat, or just watch Netflix while chopping the onions.

The Nest Hub Max is our favourite, because it packs a lot of intelligence into a decent 10-inch screen. With a built-in camera that doubles as a security camera, it can recognise who is using it and serve up personalised information (your calendar appointments for the day, not your spouse's) without you even having to say a word.



Best Smart Speaker

Sonos One

£199 | **BUY FROM** SONOS.COM | **WORKS WITH** AMAZON ALEXA, GOOGLE ASSISTANT, APPLE AIRPLAY 2

Smart speakers do many useful things, like playing music, reading the news and keeping your shopping list up to date. But they come into their own when paired with connected gadgets such as lights, plugs and thermostats, allowing you to control all these things with your voice, either individually or as part of a home-automation routine (when a few actions are strung together to happen simultaneously, based on one trigger).

The Sonos One is our pick for a smart speaker as it works with both Amazon Alexa and Google Assistant. It provides excellent sound and hooks into Sonos's wider world of wireless music. It also works with Apple's AirPlay system to let you play music directly from your Apple devices and group with other AirPlay 2-compatible speakers.



Best Smart Smoke Alarm

Nest Protect Smoke & CO

£109 | **BUY FROM** STORE.GOOGLE.COM | **WORKS WITH** GOOGLE ASSISTANT

One of the simplest yet most effective home-automation devices is a smart smoke alarm. It's not the most exciting of gadgets, but it's one of the most important. A connected smoke alarm not only alerts you if there's a fire, but also sends an alarm to your phone so if you're away you can summon help quicker.

Packed with sensors and smarts, the Nest Protect Smart Smoke & CO Alarm is the best device. At £109 a pop it will cost a bit to outfit a whole house, but it elevates the smoke alarm from noisy nuisance to helpful assistant – delivering an early warning when smoke is building via a calm voice and letting you silence nuisance alarms from your phone.

In a real emergency, it can wirelessly connect to other alarms, triggering them all to make sure you wake up. It also delivers a voice alert telling you which room the danger is in, and lights your way with a red LED (easier to see through smoke), as well as sending an alarm to your phone.



Best Smart Plug

TP Link Mini, Eve Energy

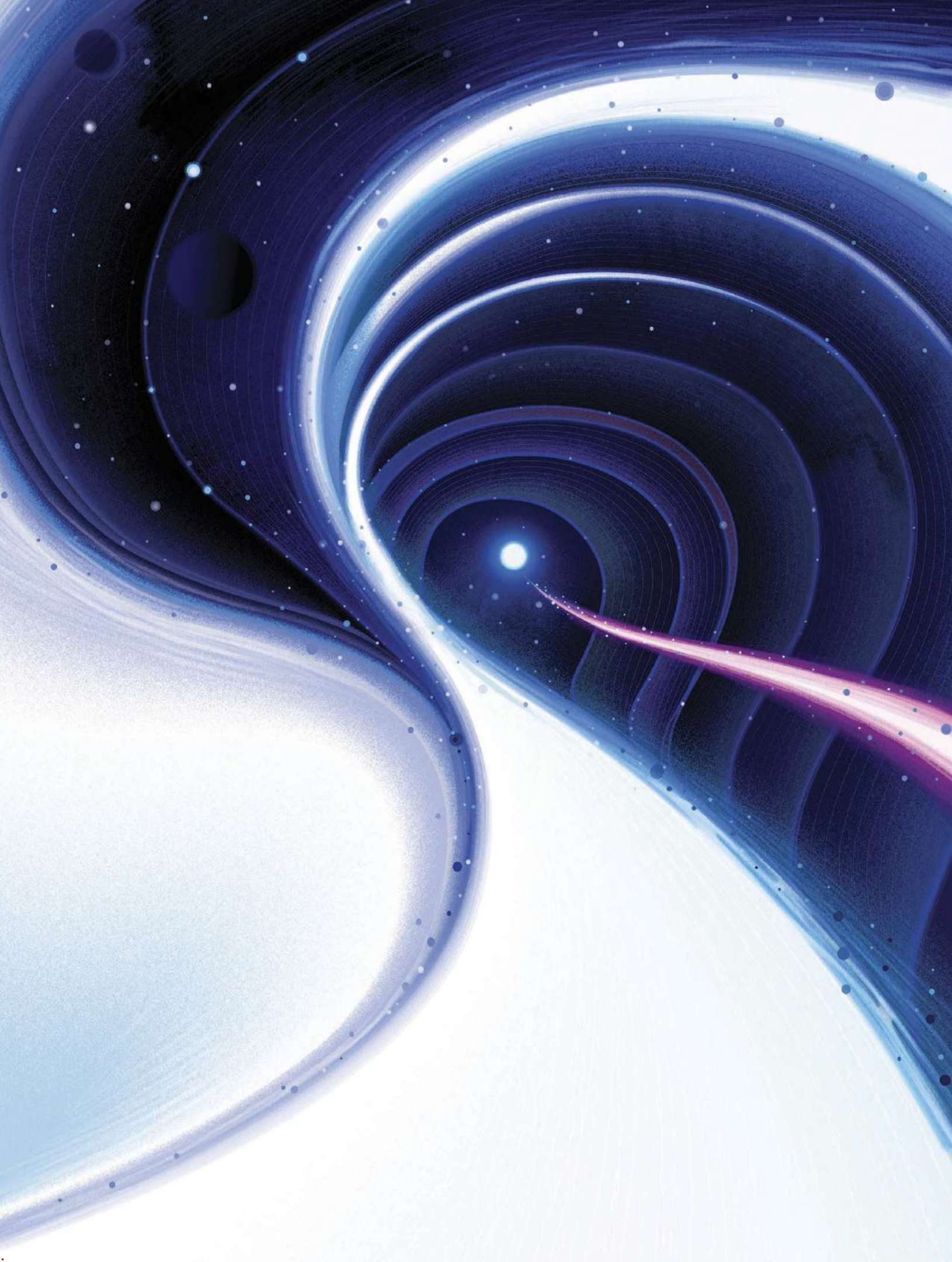
TP LINK FROM £12.99 | **BUY FROM** TP-LINK.COM | **WORKS WITH** AMAZON ALEXA, GOOGLE ASSISTANT
EVE FROM £49.99 | **BUY FROM** EVEHOME.COM | **WORKS WITH** APPLE HOMEKIT

There are still plenty of gadgets you can't automate, or whose smart version is crazy expensive (we're looking at you, smart kettles). For these, a smart plug is a simple solution. Basically a socket with a chip in it, a smart plug adds voice and/or app control to anything plugged into it, plus lets you turn it on or off

on a schedule for generally less than £20.

We love the TP Link Kasa line of smart plugs, as they're easy to use, work with Google and Alexa and have a really nice app if you don't want to use a separate smart home system to control them. Plug your kettle into one, and have it turn on just before you get out of bed each morning. Or stick one on your space heater (check the voltage requirements) and have a toasty living room ready for you when you get home.

If you're looking for a good HomeKit smart plug, the Eve Energy one is an excellent – if slightly pricey – choice that also monitors energy use, providing you with a detailed breakdown of consumption over time. It offers the option of inputting your rate, for real-time visuals of how much that kettle is costing you.



MYSTERIES OF THE UNIVERSE

In the last decade, we've taken photos of a black holes, peered into the heart of atoms and looked back at the birth of the Universe. And yet, there are yawning gaps in our understanding of the Universe and the laws that govern it. These are the mysteries that will be troubling physicists and astronomers over the next decade and beyond

WORDS MARCUS CHOWN

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WHY IS THERE
SOMETHING
RATHER THAN
NOTHING?

In the beginning, according to the standard picture of cosmology, was the 'inflationary vacuum'. It had a super-high energy density and repulsive gravity, causing it to expand. The more of it there was, the greater the repulsion and the faster it expanded. In common with all things 'quantum', this vacuum was unpredictable. At random locations, it decayed into ordinary, everyday vacuum. The tremendous energy of the inflationary vacuum had to go somewhere. And it went into creating matter and heating it to a blisteringly high-temperature – into creating big bangs. Our Universe is merely one such Big Bang bubble in the ever-expanding inflationary vacuum.

Remarkably, this whole process could have started with a piece of inflationary vacuum with a mass equivalent to a bag of sugar. And, conveniently, the laws of physics – specifically, quantum theory – permit such matter to pop into existence from

nothing. Of course, the next obvious question now is: where did the laws of physics come from?

In 1918, German mathematician Emmy Noether shed light on this. She found that the great conservation laws are mere consequences of deep symmetries of space and time – things that stay the same if our viewpoint changes. A striking property of such symmetries is that they are also symmetries of the void – of an entirely empty Universe. So maybe the transition from nothing to something was not such a big deal. Maybe it was simply a change from nothing to the 'structured' nothing of our galaxy-filled Universe. But why did the change happen? The American physicist Victor Stenger pointed to the fact that, as the temperature drops, water turns into structured water, or ice, because ice is more stable. Could it be, he speculated, that the Universe went from nothing to 'structured nothing' because structured nothing is more stable?

**WHY IS THERE A
MONSTER BLACK HOLE IN
THE HEART OF EVERY
GALAXY AND DOES IT
HAVE ANYTHING TO DO
WITH US BEING HERE?**

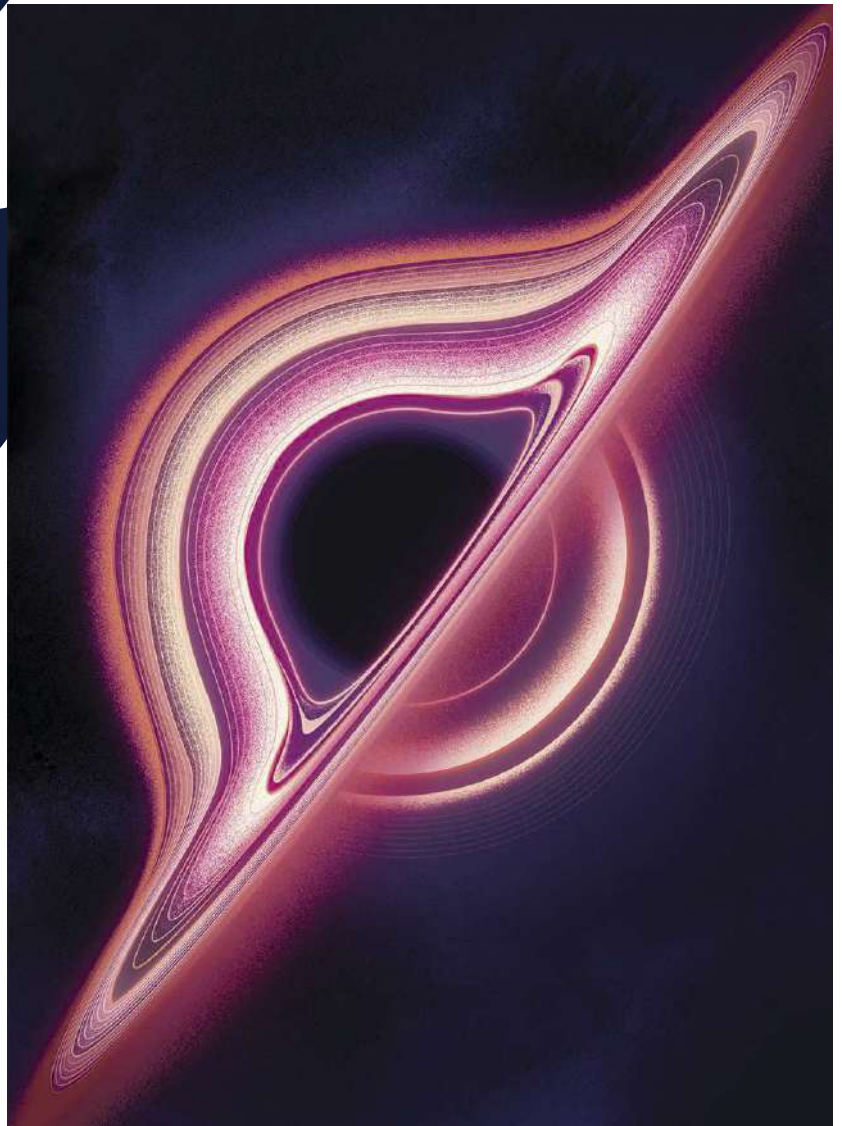
There are about two trillion galaxies in our Universe and, as far as we know, almost every one contains a central supermassive black hole. They range in size from monsters, weighing almost 50 billion times the mass of the Sun, to the 4.3-million-solar-mass tiddler known as Sagittarius A* in the core of our Milky Way (one solar mass = mass of our Sun). But how they got there is one of the great unsolved mysteries of cosmology.

We know that a stellar black hole forms in a supernova explosion in which the core of a star implodes. But nobody knows how a supermassive black hole forms. For most of cosmic history, the centres of galaxies have been where a lot of matter is confined in a small volume. It could be the case that supermassive black holes form in a dense star cluster out of stellar black holes which repeatedly merge with each other. Tentative evidence for this comes from a merger between two black holes revealed by a recent detection of gravitational waves. One hole was too big to be a supernova relic and so may have originated in an earlier merger.

An alternative way to form a supermassive black hole is from the direct shrinkage of a dense cloud of gas. It could be that they form from a combination of cloud collapse and black hole mergers. It is also possible that supermassive black holes formed in the Big Bang. This would provide a novel answer to the cosmic chicken-and-egg question: which came first – galaxies or supermassive black holes? Rather than galaxies forming first and then spawning

such monsters, supermassive black holes would form first and provide the seeds about which galaxies of stars formed.

Despite their masses, even the biggest supermassive black holes are hardly bigger than the Solar System. Yet they project their power across millions of light-years by means of oppositely directed super-fast jets of matter. Where such jets are fast – in the inner regions of a galaxy – they drive away gas and snuff out star formation; where they have slowed – in the outer regions – they compress gas and trigger star formation. In fact, powerful jets from the biggest holes seem to control the masses of stars that form, with a tendency towards smaller, cooler stars like our Sun. So, who knows, it might be the case that we can thank Sagittarius A* for our Sun, without which you probably wouldn't be reading this page.



WHAT IS THE IDENTITY OF
THE DARK MATTER THAT
HUGELY OUTWEIGHS THE
STARS AND GALAXIES?

Dark matter gives out no light or too little light for us to detect. We know it exists because we see the effect of its gravity on the visible stars and galaxies. For instance, the Milky Way could not have dragged in enough matter to make its stars in the 13.82 billion years since the Big Bang without there being a lot of invisible matter whose extra gravity speeded things up.

The European Space Agency's Planck satellite found that dark matter accounts for 26.8 per cent of the mass-energy of the Universe compared with the 4.5 per cent of normal 'atomic'

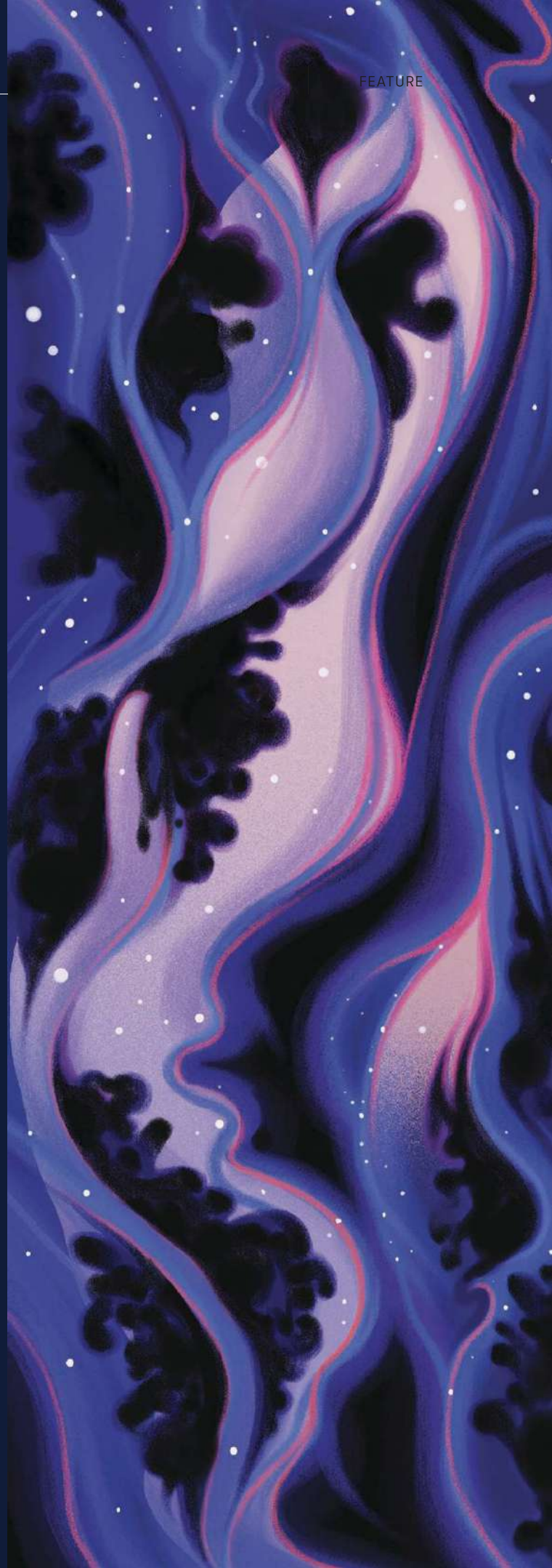


**“No Earth-based
experiment has found any
dark matter, despite
decades of searching”**

matter. It therefore outweighs the visible stars and galaxies by a factor of about six.

For a long time, the favoured candidates for dark matter particles have been Weakly Interacting Massive Particles, or WIMPs. But although these particles fit the bill, they have failed to appear at the Large Hadron Collider near Geneva in Switzerland. A candidate gaining favour is the super-light 'axion', a hypothetical subatomic particle. A rank outsider remains primordial black holes, left over from the Big Bang.

Puzzlingly, no Earth-based experiment has found any evidence of dark matter, despite decades of searching. It is conceivable that it is not our theory of matter that needs modification but our theory of gravity. Or that dark matter is not a fluid made of a single particle but is complex like the atomic matter we see around us. Maybe the Universe is filled with dark stars and dark planets and dark life!





4 DOES TIME EXIST?

Time is what stops everything happening at once,” said American physicist John Wheeler. But time is a slippery concept. Most of what we think we know is false. For instance, we imagine time flowing. However, for something to flow, it must flow with respect to something else, just as a river flows with respect to a river bank. Does time flow with respect to something else – a second type of time? The idea seems nonsensical. Most likely, the flow of time is an illusion created by our brains to organise the information constantly flooding in through our senses.

We also have a strong sense of a shared past, present and future. However, the idea of a common present appears nowhere in our fundamental description of reality: relativity. Precisely how someone else's time is sliced up depends on how fast they are moving relative to you or the strength of the gravity they are experiencing. These effects

are noticeable only at relative speeds close to that of light or in ultra-strong gravity, which is why they are not obvious in the everyday world. Nevertheless, they lead to the idea that one person's interval of time is not the same as another person's, and that one person's interval of space is not the same as another's.

Actually, it is worse. Space and time are inextricably intertwined. In our Universe, all events – from the Big Bang to the death of the Universe – are laid out in a pre-existing four-dimensional space-time map. Nothing actually ‘moves’ through time. As Einstein wrote after the death of his friend Michele Besso: “Now he has departed from this strange world a little ahead of me. That means nothing. People like us, who believe in physics, know that the distinction between past, present and future is only a stubbornly persistent illusion.”

If the expansion of the Universe is imagined running backwards like a movie in reverse, in its earliest moments space and time are both ripped apart. Physicists therefore suspect that in the Big Bang time emerged from something more fundamental. As yet, no one knows what that might be.

5 WHAT IS DARK ENERGY?

It's invisible, fills all of space and its repulsive gravity is speeding up the expansion of the Universe. ‘Dark energy’ was discovered by astrophysicists in 1998. They were studying type 1A supernovae – stellar explosions believed to unleash a fixed amount of energy and burn with a standard luminosity like a cosmic 100W lightbulb. The problem was that the most distant supernovae were fainter than expected. Cosmic expansion had speeded up, pushing them further away.

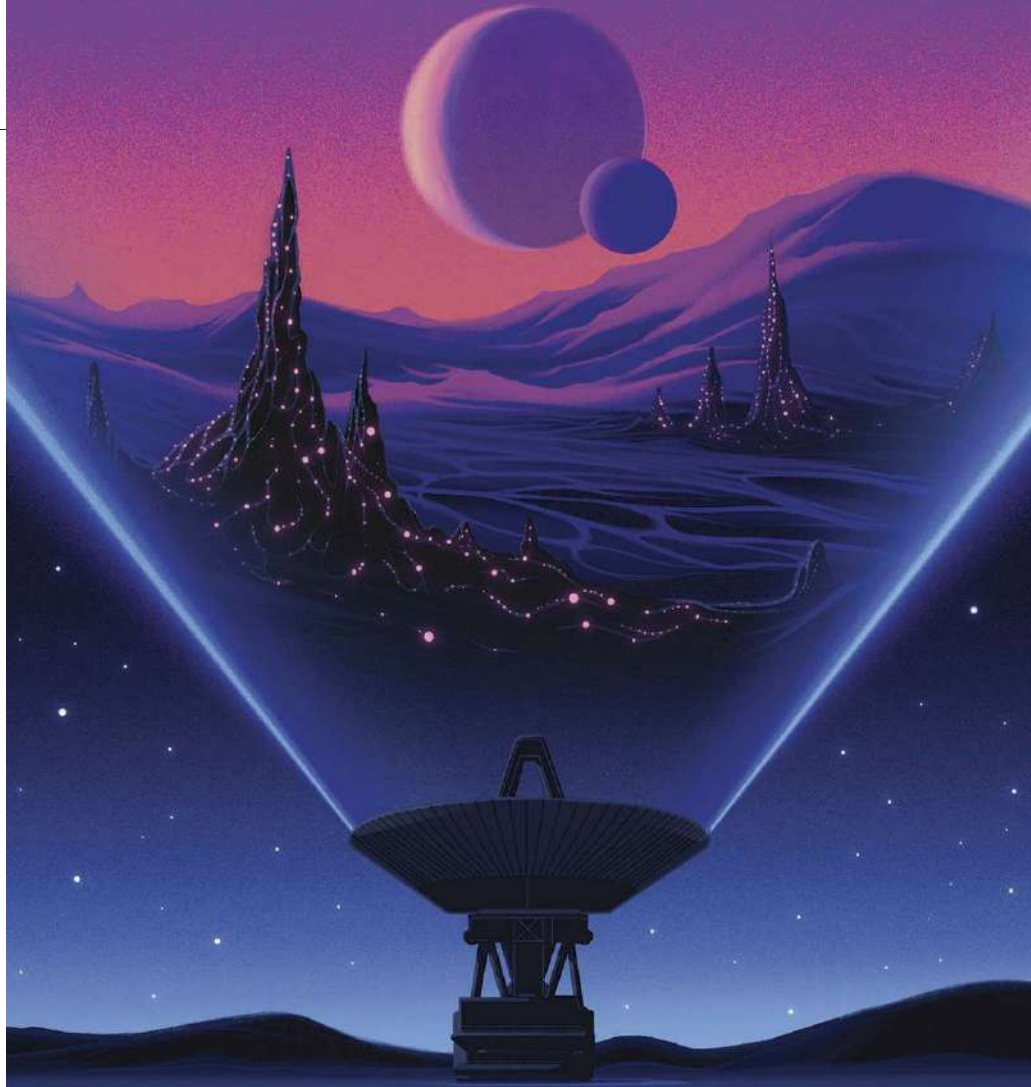
At the time, the only force thought to be operating in the large-scale Universe was gravity, which acts like an invisible web between the galaxies, braking cosmic expansion. The discovery that the expansion of space was speeding up gobsmacked cosmologists who were forced to postulate the existence of a substance that accounts for an astonishing two-thirds of the mass-energy of the Universe. This ‘dark energy’ overwhelmed gravity and gained control of the Universe about five billion years ago.

One possibility is that dark energy is a cosmological constant, an intrinsic repulsion of space. Such repulsion might arise from quantum energy fluctuations in the vacuum. However, when quantum theory, our best theory of the submicroscopic world, is applied to the vacuum, theorists predict an energy density that is 10 followed by 120 zeros bigger than that of the dark energy: the biggest discrepancy between a prediction and an observation in the history of science. Conceivably, the discrepancy will disappear when we finally manage to combine quantum theory with Einstein's theory of gravity. Meanwhile, space experiments may help. In 2022, the European Space Agency will launch Euclid, which will measure how dark energy varies with cosmic time, hopefully providing a vital clue to solving what is the biggest puzzle in science.



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“We have searched a mere fraction of the Galaxy, equivalent to the water in a hot tub compared to that in Earth’s oceans”



WHY HAVE WE SEEN NO SIGN OF ALIENS?

In 1950, Enrico Fermi, the man who built the first nuclear reactor, was having lunch in the canteen of the Los Alamos bomb lab in New Mexico when he suddenly said: “Where is everybody?” Everyone around the table knew exactly what he meant.

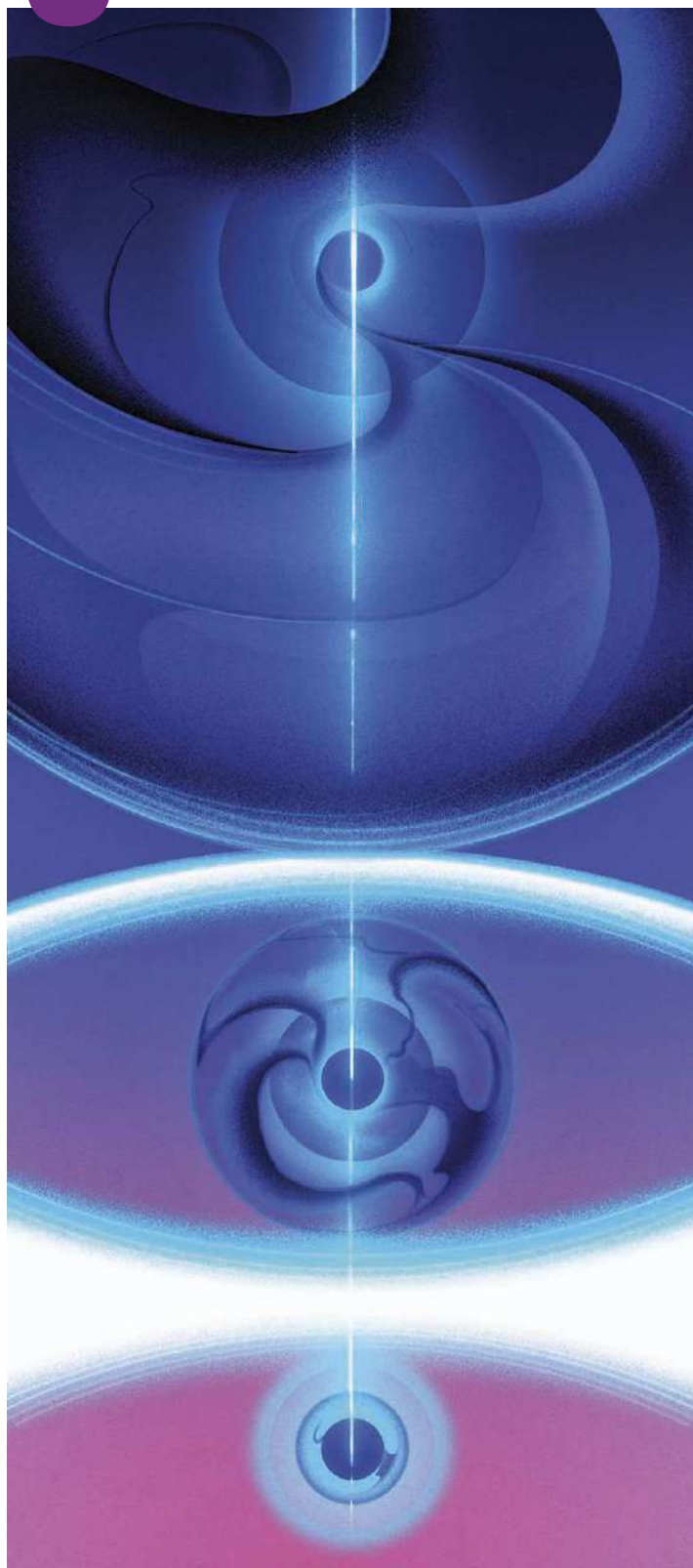
Decades later, Fermi’s question was examined independently by the American physicists Michael Hart and Frank Tipler. Hart considered aliens spreading throughout our Milky Way and Tipler considered self-replicating machines that, on arrival at a planetary system, exploit the resources to build two copies of themselves that continue voyaging. Both concluded that, even at modest speeds of travel, every star in the Galaxy would be visited in a fraction of the age of the Milky Way. As Fermi realised, the aliens should be here on Earth. They do not appear to be. This became the ‘Fermi paradox’.

Hundreds of explanations have been proposed. They include the ideas that we are the first intelligence to arise in the Galaxy and so are totally alone, and

that we are a nursery world, off-limits to advanced civilisations that might adversely affect our development. A more mundane possibility is that there is no paradox, because any signs of visitation in the distant past would be erased by wind, rain and geological processes. Recently, however, a team led by Dr Jonathan Carroll-Nellenback of the University of Rochester, New York, has proposed that our Sun may simply have been bypassed by a wave of extraterrestrial expansion.

There remains the question of why we have seen no sign of extraterrestrials in our Galaxy, despite searching with telescopes for more than half a century. However, a Pennsylvania State University team led by Dr Jason Wright says there is no mystery: we have searched a mere fraction of the Galaxy, equivalent to the water in a hot tub compared to that in Earth’s oceans. As Douglas Adams observed so perceptively in *The Hitchhiker’s Guide To The Galaxy*: “Space is big. You just won’t believe how vastly, hugely, mind-bogglingly big it is.”

WHY HAS NATURE TRIPLICATED ITS BASIC BUILDING BLOCKS?



Say Lego launched a version of its bricks in which each brick was hundreds of times bigger than a standard brick. And say it then launched another version in which the bricks were thousands of times bigger. You would be forgiven for thinking the company had gone bonkers. But this is exactly what nature has done with its fundamental building blocks – the quarks and leptons.

Normal matter is made of just two kinds of quark and two kinds of lepton. But there also exists a second 'generation' of quarks and leptons in which all the particles are identical to the first apart from being hundreds of times heavier, and a third generation in which they are identical but thousands of times heavier. The heavier generations take a lot of energy to create so are rarely seen today. However, it is likely they played some critical role in the Big Bang. But why the wildly different masses of the particles in each generation? Dr Steven Weinberg, an American physicist and Nobel laureate, has recently made an interesting speculation.

The basic building blocks of matter gain their masses by interacting with the Higgs field, an invisible fluid that fills all of space. You can think of them interacting with the Higgs particle, a localised hummock in this energy field. Weinberg points out that particles which interact most strongly with the Higgs field end up with masses close to that of the Higgs particle, and these are the particles of not of the first but the third generation. Maybe, speculates Weinberg, they are the only particles that interact directly with the Higgs. Maybe the second generation get their masses by interacting with an undiscovered particle that interacts directly with the Higgs. And maybe the first generation get theirs by interacting with a second undiscovered particle that interacts with the first.

It is like that playground game in which a message is passed down a line of children and what is relayed gets ever further removed from what was originally said. Perhaps with each lower generation, the particles become further removed from 'feeling' the Higgs field, so its mass-generating effect is ever diluted. Weinberg does not know how such a mechanism could work in detail. But other physicists feel he may have provided a hint of how to solve the puzzle of nature's triplicated building blocks. **SF**

by **MARCUS CHOWN**

Marcus's most recent book is The Magicians: Great Minds And The Central Miracle Of Science (£14.99, Faber & Faber).

ILLUSTRATIONS: SAM CHIVERS

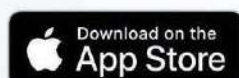
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BEAT THE BURNOUT

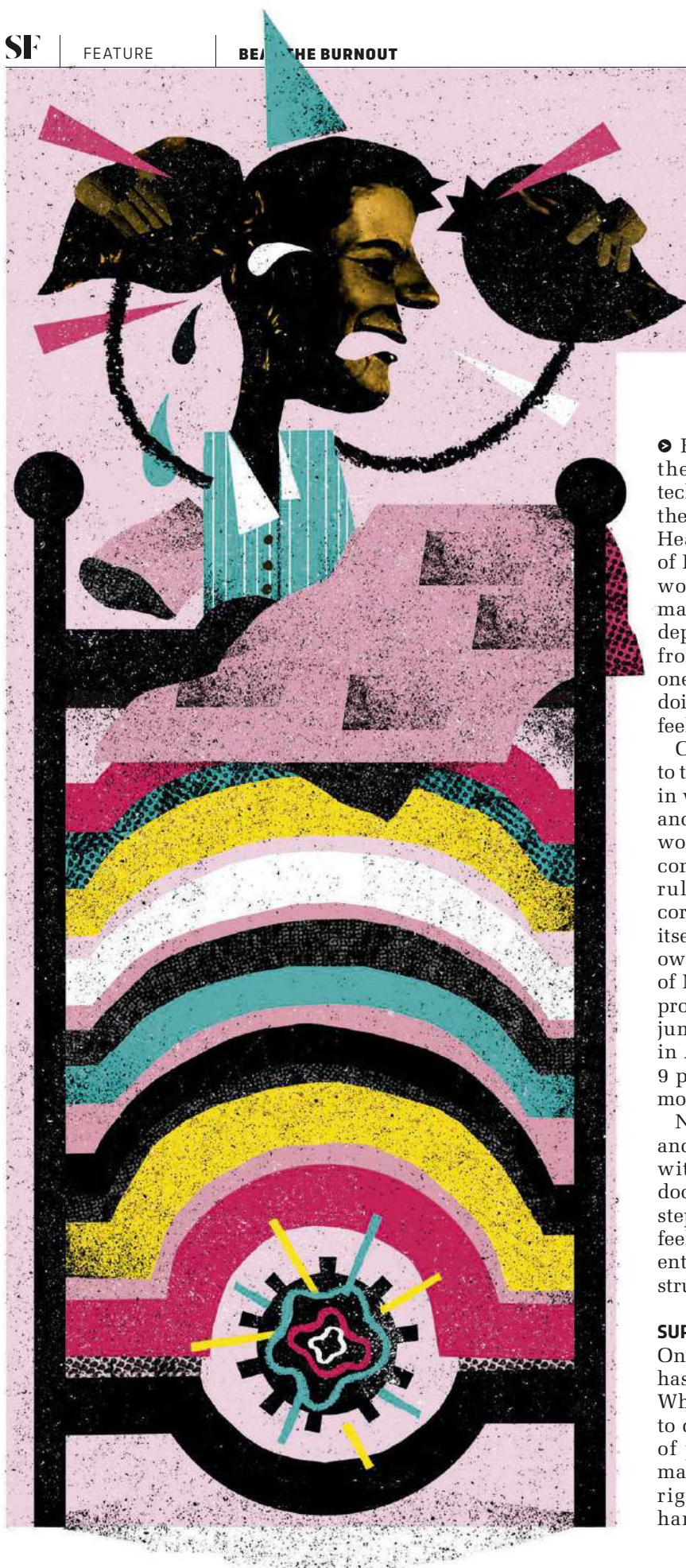
HOW SCIENCE CAN HELP YOU GET THE BETTER OF PANDEMIC FATIGUE

WORDS AMY FLEMING

January can suck the wind from our sails in the best of years, but this is not just any January – it's our very first pandemic January. This doesn't necessarily mean it will be worse than ever. Life can be gloriously contrary and you might end up having a pleasant, cosy month. But there's no denying that, even among those who aren't grieving or recovering from infection, COVID burnout is real and as contagious as the virus itself. No one should beat themselves up about feeling fatigued right now. ☺







➤ Burnout was already doing a swift trade before the pandemic came along, steadily spreading as technology allowed everyone to carry their inboxes in their pockets. The term was even added to the World Health Organization's International Classification of Diseases in 2019, listed as the result of "chronic workplace stress that has not been successfully managed". Symptoms include a sense of, "energy depletion or exhaustion... increased mental distance from one's job... negativism or cynicism related to one's job" and feeling less efficient and effective at doing said job. That wading-through-treacle sensation feels painfully familiar right now.

COVID burnout, however, is a new version, peculiar to these uncharted pandemic times. 2020 was the year in which our homes became our offices, our schools, and at times felt like our prisons. The lines between work and leisure blurred, without even our daily commutes to bookend business hours. Uncertainty ruled, and the grim compulsion to stay on top of coronavirus-related news felt like a full-time job in itself. But pandemic burnout is too novel to warrant its own statistics or entries in medical books. The Office of National Statistics can tell us, however, that the proportion of adults reporting psychological distress jumped from 24.3 per cent in 2019 to 37.8 per cent in April 2020, and that sleep problems increased by 9 per cent last year, with young adults and women most likely to report worse wellbeing.

No matter how exhausted you are, or how impossible and unappealing your to-do list may seem, be armed with the knowledge that you are not necessarily doomed to stagnate until conditions improve. Positive steps can be taken at any time to fend off burnout and feel better. And once you're out on the other side, it's entirely possible that you will be stronger for your struggles—a phenomenon called post-traumatic growth.

SUPPORT GROUP

One of the greatest challenges of imposed isolation has been feeling cut off from friends and colleagues. When life is overwhelming, it's easy to let efforts to connect slip. But Dr Steven Southwick, professor of psychiatry at Yale Medical School, says that maintaining relationships should be a top priority right now. "The fundamental need to belong is hardwired into our nervous system," he says. "In

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“Some of the same areas of the brain that are activated during physical pain are also activated during social pain”

fact, from a neurobiological standpoint, exclusion, rejection or isolation can activate the sympathetic [fight or flight] nervous system just like any fear response. Adrenaline, noradrenaline, cortisol, all of these stress hormones can get activated purely by social isolation.” It turns out, he says, that some of the same areas of the brain that are activated during physical pain are also activated during social pain.

On the other hand, says Southwick, positive social support can quieten the fear response. “When people are cooperating with one another, you can see activation of reward centres in the brain,” he explains. Social connectedness releases oxytocin, too, which also “quiets anxiety through a variety of mechanisms.”

In May 2020, Southwick wrote a paper for the journal *JAMA Psychiatry* stating the loss of social connectedness at work – spending increasing periods on screenwork, a loss of camaraderie with little time to talk with peers, running from one task to the next – is a major contributor to the burnout experienced by physicians. But he says the same is true for anyone overwhelmed by pandemic life.

Ask yourself, suggests Southwick, “How many friends, colleagues, family members, do you have that you could call at any time? Similarly, how many people would you help at the drop of a hat?” According to a study published in 2003 in the journal *Psychological Science*, giving social support can be even more protective than receiving social support.

Another key problem with burnout is a loss of agency. Southwick says that the more positive social connections you ●



● have, the more meaningful your life feels. “While you’re locked down, and social distancing, it’s important to take the time to say, ‘Well, what is my purpose? How can I advance my purpose, even during this difficult time?’”

BE IN CONTROL

Social connection can even enhance your problem-solving abilities in challenging times. Some of the most effective coping mechanisms are those that are activated in the throes of stressful moments to lessen any negative effects. This is known as ‘active coping’ as opposed to ‘passive coping’. “If you have a strong social network, you tend to use more active coping, because you know somebody has your back,” says Southwick.

The disempowering feeling of not having control over your situation is another common burnout contributor. “We often think of stress as being bad, but it’s not necessarily bad,” says Southwick. “What makes it toxic is when we believe that we cannot control the stress.”

An active coping strategy here would be to sit down and assess just what you can and can’t control. “I can’t control the fact that the virus is here, but I can control how I respond to it,” he says. “It’s very powerful to accept that which is out of your control, and to work on that which is in your control. You can try to manage the inflow of negative information. You can follow evidence-based advice from trusted sources. You can share your concerns and fears with trusted colleagues.”

Likewise, he says, you can try relaxation techniques, from breathing to mindfulness, which engage the parasympathetic nervous system. You can ask yourself, ‘is there something that I can learn from this experience?’. If possible, Southwick says you can try to reframe this horrible situation as a challenge.

The increasingly popular notion of eustress, or beneficial stress, can be useful here. A certain degree of stress is necessary to help you grow, just as putting a stress on your body by lifting weights builds up muscle. Unlike damaging, chronic stress, eustress is this kind of healthy stress, but sometimes the same stressors involved in chronic stress can be reframed as eustress. Taking simple steps to train a more positive outlook can help with this.

Clinical psychologist Linda Blair is an expert in helping people out of the doldrums. “When you’re so



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“If you can accomplish just one small thing each day, whether it’s making a nicer dinner than you normally would, or calling a friend, then you will maintain an equilibrium”

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tired and fed up that you can't carry out the activities that either you're required to carry out or that you really want to carry out, then I would say that burnout is official," she says. "Sometimes, a really good thing to do is to mentally fly over the pile of rubbish which is right now. On the other side is stuff you didn't know was there." Dreaming about possibilities, such as holidays, when this is all over can be deeply soothing. "Research shows without a doubt that the happiest aspect of a holiday is the planning," she says.

Show yourself some kindness, she continues. "Congratulate yourself that you have coped so well for so long. You need to give yourself a lot of slack for how tired you are." And then focus on instilling some healthy routines. "If you can accomplish just one small thing each day, whether it's making a nicer dinner than you normally would, or calling a friend,

and exercise within whatever your limits are, then you will maintain an equilibrium."

Avoiding sugar should help your energy levels, says Blair, and avoid alcohol if possible. Alcohol is a depressant after the initial relaxation. But there's nothing wrong with seeking escapism in box sets *per se*. "Distraction is great because it gives you a temporary break, but don't just choose any old box set that you know well. You need one that challenges your mind a little bit." This is not, however, an open invitation to surrender into couch-potato life. Sneak in a bit of stand-up viewing, or even do a few press-ups. "It's easy and small doses add up," she says.

To swing your default mental setting back from negative to positive, Blair recommends the evidence-based practice of creating an evening routine that involves either writing down any goals that you ►

HOW PANDEMIC BURNOUT COULD MAKE YOU STRONGER

Until recently, the general consensus was that burnout left those who had experienced it a little bit broken. But in late 2019, Dr Judith Semeijn, professor of sustainable human resources management at the Open University in the Netherlands, and her colleague Greet Vonk, who works clinically with people recovering from burnout, discovered that it doesn't have to be this way. Although it may not feel like it at the time, recovering from burnout can leave you even stronger than before.

In the study, which was published in the *International Journal Of Workplace Health Management*, 166 research participants who had all been previously clinically diagnosed

with burnout and had all fully recovered already, were each scored on their markers for post-traumatic growth – having gained new insights and resources as a result of their burnout experience. They were also surveyed on their current levels of burnout complaints, such as cynicism, exhaustion and inefficiency. All of them reported fewer signs of burnout than the general population, and these signs further decreased in correlation with the more post-traumatic growth they'd exhibited.

The bolstering effects of their new, stronger, more resourceful selves did not weaken over time. "Whether their recovery was a year ago or 10 years ago, they all profit

♦ have accomplished, or asking two simple things: who am I grateful to, and what am I grateful for today? It takes about four or five weeks for the effects to bed in, she says, but it's worth it. Benefits can include a boost in happiness, reduction in anxiety and depression, and improved sleep.

MOVE MORE

Naturally, both Blair and Southwick are adamant that exercise is essential for busting out of burnout. When you're feeling too tired to lift a finger, exercise could be your ticket out of this purgatory because it will improve how energetic you feel. "Rather than being an argument to avoid activity, your perceived exhaustion should be an argument to be active, because we know that it will increase your subjective energy," says Dr Boris Cheval, a health neuropsychologist at the Swiss Centre for Affective Sciences in Geneva.

Cheval and colleagues made headlines in 2018 when they identified how we are wired to conserve energy, and, in the name of efficiency, have a nice sit down whenever possible. Their small study, published in the journal *Neuropsychologia*, used electrodes to measure volunteers' brain activity and found that even if we have great plans to be active, our brains appear to be attracted to being sedentary. So firstly, do not feel like you're a failure or a wimp for skipping exercise. Even the act of egging ourselves on to being active is mentally tiring. "You need to activate your brain to counteract your tendency to be inactive," says Cheval.

The good thing is, with practice, we can override this negative impulse. Through his studies on the impediments to exercise, he has learned that you're more likely to get out there if you like the activity, and you don't feel under pressure to do it. A common



ILLUSTRATIONS: JAMES MINCHALL

still from their experiences,” says Semeijn. “After their recoveries from burnout, they were able to regain resources and to develop new ones, so they’ve gained a new perspective,” she adds. Such a resource might be an ability, for example, to see through the fog of lockdown exhaustion and recognise that you need to look for some help with childcare and see whether you can relax for a couple of hours.

The researchers observed that people who have beaten their burnout see their lives as before and after burnout, just like people who have had life-changing accidents. Similarly, many of us around the world will view our lives as before COVID and after.



stumbling block is picking something too hard, which will leave your brain with negative associations. “If you choose a low-to-moderate intensity exercise, this will be associated with positive affective experience, which will increase the likelihood of maintaining and repeating the behaviour,” he says. He refers to this result pleasingly as a virtuous circle, as opposed to a vicious circle. As a guide, he says, activities that still allow you to speak while doing them work best.

Another strategy to bypass what Cheval calls “sedentary temptation” is to use implementation intentions to automatically activate your chosen healthy behaviour. If you want to go for a hike tomorrow morning, for example, then leave your raincoat and boots by the door. It’s simple, and it works.

Sometimes, no matter how much exercise or positive action you take to cope with mounting challenges, your brain can simply become overloaded – be it with extra work to cover for sick colleagues or all the added responsibilities that the coronavirus has thrown at us.

But there is a surprising hidden benefit to being in this overloaded state. In 2015, experimental psychologists at the University of Nice Sophia-Antipolis, published a paper in the journal *Cognition* that found that mental exhaustion can boost creative thinking, by loosening your inhibitions. Eccentric, free-flowing ideas that our over-sensible alert brains might filter out, are allowed to surface. So there’s another reason not to panic about feeling exhausted.

There is both light at the end of the tunnel, and even glimmers within it if you look for them. **SF**

—
by **AMY FLEMING**
Amy is a freelance
science and health
writer.

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COMMENT

LET'S REWRITE THE FUTURE

By repeating the mistakes of the past, we're dooming the future. It's time to come up with some new ideas

Can you believe it's been a year since the pandemic first shut normal operations down? While we continue to grapple with our new beginning and what stories we will tell about the past, I want to tell a story about the future.

In 2016, I started a writing project codenamed 'Teach your toddler to type: a toolkit for the 21st Century'. The title was a deliberate provocation aimed at mum blogs, who I predicted would read it at face value and call me the devil for suggesting we replace pen and paper with keyboard shortcuts. In fact, it wasn't a parenting manual, but an intervention in outdated ideas about the future that were hamstrung by intractable legacy thinking.

Modern advice for parents is more reflective of our own and our parents' childhoods than what will be useful in 2036. My upbringing in 1970s America was informed by my mum's youngest years in post-war Lancashire, where her parents, fresh from the horrors of occupied Poland, tried to do what they could do to reinvent a humanity that had proved it wasn't fit for purpose.

My expectations on entering adulthood were based on the stories

"Hack the past and design the future now, so we can liberate the next generations from us"

my mum's mum had heard from her mum. Each generation felt they had to pass on these stories to give us the tools to succeed. But within them are expectations about gender, politics, race and righteousness, and who can aspire to what. These lessons are what we fall back on to get us through crises, but they leave little space for reinvention for the now – the thing that will end up shaping the next.

'Teach your toddler to type' was cut from the same cloth as UNESCO's 'Futures Literacy'. UNESCO says that Futures Literacy is "the skill that allows people to better understand the role of the future in what they see and do". In December 2020, they launched The Museum of Future History. It's a virtual (at present)

exercise in revealing how the future is colonised by ideas from the past. It exposes the ways the present has been pre-emptively defined by previous generations, and what we've lost as a result. It invites people to hack the past to design the future now, so we can liberate the next generations from us.

If your brain is temporal soup right now, think about what we are going through. How are you going to tell the tale of COVID? Who are the major players? What advice will you pass on? When the next global health crisis comes, what will you place your faith in? Who will be valued? What role will you be allowed to play? What we imagine now changes what we can perceive, what we will imagine, and what we will be able to do.

Recognising that the answers to these questions are baked into us because of the past means that we can come up with new ideas to solve problems. The last 12 months have been dominated by anxiety about uncertainty. If we can tell a story that liberates the future from that one thing, toddlers of today will be able to face whatever comes their way. **ST**



ALEKS KROTOSKI

Aleks is a social psychologist, broadcaster and journalist. She presents *The Digital Human*.



COMMENT

DON'T BLOW YOUR TOP

It's vital to keep your blood pressure healthy.
This is how I keep an eye on mine



This Christmas, I asked my wife for a blood pressure monitor. It's not the most romantic of presents, but it certainly beats socks.

I have a family history of heart disease, and I am aware that people with high blood pressure rarely have symptoms. So unless you are tested, you probably won't know you have a problem until you have a heart attack or stroke. And new research suggests that long-term damage is happening to your brain, even when blood pressure is only slightly above what would be considered 'normal'.

In a recent study published in November in the *European Heart Journal*, researchers at the University of Oxford looked at MRI brain scans of 37,041 people who'd had their blood pressure measured around 10 years earlier. The researchers found that even mildly elevated blood pressure levels, below the usual treatment threshold, were linked to damage to the small blood vessels in the brain.

An ideal healthy systolic blood pressure is between 90 and 120mmHg, so what can you do if your blood pressure is slightly too high? Well, losing a bit of weight, exercising more and stopping smoking will all help, but so can consuming certain foods – or at least that is what we discovered on *Trust Me, I'm A Doctor*, when we did a small experiment with Dr Andy Webb at King's College, London, a few years ago.

“Mildly elevated blood pressure was linked to damage to the small blood vessels in the brain”

We wanted to test the claims that beetroot, garlic and watermelon could lower blood pressure. All three foods are said to work by boosting levels of nitric oxide in the body, which in turn causes blood vessels to open up and blood pressure to fall.

We selected 28 volunteers who all had blood pressures just above the healthy range and divided them into three groups. For the first week of our small experiment, group one ate two cloves of garlic a day, while group two ate two large slices of watermelon a day and group three ate two whole beetroots. Yummy!

For the second and third week, each group swapped over so that

after three weeks everyone had eaten their fill of each food.

So what happened? Well the average systolic blood pressure of the volunteers at the start was 133.6 mmHg. On the beetroot diet, this went down to 128.7mmHg. Consuming two cloves of garlic a day gave a similar result (129.3mmHg). This is similar to what has been found in larger studies. There was, however, disappointment for watermelon lovers, with consumption leading to very modest changes.

A fall in blood pressure of around 5mmHg doesn't sound a lot, but studies suggest that if was maintained it would translate into a reduction of the risk of stroke and heart attack of around 10 per cent.

I love garlic and I am happy to pile my plate with beetroot and other nitrate-rich veg, such as rocket, spinach, chard and broccoli. And if, like me, your blood pressure is a bit suspect, you might want to invest in a home blood pressure monitor or ask for one for your birthday. **SF**



MICHAEL MOSLEY

Michael is a writer and broadcaster, who presents *Trust Me, I'm A Doctor*. His latest book is *COVID-19: Everything You Need To Know About Coronavirus And The Race For The Vaccine* (£6.99, Short Books).



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THE SEASONS OF YOU

THE CALENDAR YEAR FOLLOWS THE PATTERN OF SPRING, SUMMER, AUTUMN, WINTER. BUT PERHAPS IT SHOULDN'T...

by Susan D'Agostino

Ancient Egyptians identified three seasons based on cycles of the Nile River: inundation, emergence and harvest. In tropical countries, it's the rain that tends to divide the year in two: a wet and a dry season. Elsewhere the calendar demarcates four seasons: autumn, winter, spring and summer.

But now, researchers at Stanford University have found that human biology, rather than rivers, rainfall or calendars, could be used to determine the seasons. In their study, published in the journal *Nature Communications* in October 2020, the Stanford researchers discovered our bodies seem to set their own rhythm, splitting the year into two seasonal time periods. Or at least that's the case if you live in California, where the study was carried out. Since every geographical location has unique environmental conditions, their approach may be used to count the seasons in other parts of the world too.

"People say there are four seasons of three months each. But why four? There could be 15 or could be 2. Why don't we let biology tell us?" asks Prof Michael Snyder, principal investigator of the study.

To determine the human seasons, Snyder's team profiled the biology of 105 volunteers in the San Francisco Bay area over a period of four years. They regularly sampled and measured tens of thousands of molecules and microbes

X

"The body's different molecules group into two major seasonal patterns, with one season peaking in December and the other in late April"

from the participants' blood, noses and guts. This type of study is called 'deep longitudinal multiomics profiling'.

On sample days, the researchers also collected meteorological data (such as air temperature and solar radiation) and airborne pollen counts.

This massive effort was undertaken to create a better picture of how the changing seasons might be affecting our physiology and health.

MAKING SENSE OF THE SEASONS

After four years of testing poo, taking blood samples and logging the weather, the team used powerful computational tools to try and find patterns between the volunteers' biology and their environment. What they found surprised them.

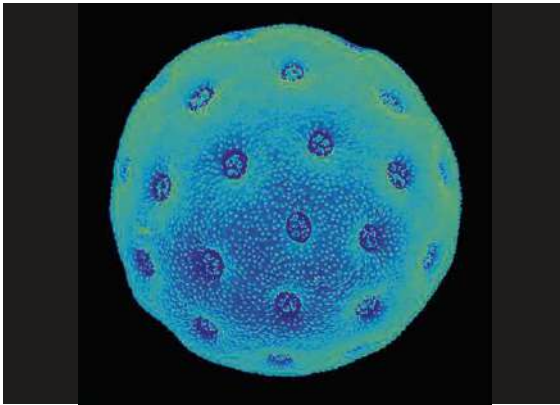
There were two signals. One was a group of molecules that seemed to peak in December – a season the researchers dubbed late fall/early winter. This included markers related to immune responses such as the complement system, a collection of proteins that work together to eliminate infectious microorganisms, which peaked during this time. Unsurprisingly, this correlated with the period we know viral infections are also high. The second signal however did come as a surprise.

"I thought the other [season] would be in June or July when it's pretty hot, but that wasn't true," Snyder says. Instead, the second season peaked in late April – a season they called 'late spring'. This season's peak made sense in hindsight, as late April also corresponded with a time of high pollen counts at the end of California's rainy season. The pollen caused a reaction in a large enough subset of people to contribute to the seasonal peak in the immune response.

The findings added nuance to earlier understandings regarding how human biology interacts with seasonal patterns in the presence or absence of disease. For example, scientists had

Study leader Prof Michael Snyder is a fan of tracking his health – he wears eight devices every day. He's keen for personalised health data to be more widespread





Pollen (seen here under a scanning electron microscope) peaks in late April in California, just as some of the participants' immune systems reached a second high point

known that the disease risk marker HbA1c (an indicator of recent average blood glucose levels) was often higher in winter than in summer for diabetic patients. What they didn't know was how levels varied throughout the year for non-diabetic patients. This study revealed that participants in general – diabetic or not – experienced peak HbA1c levels in late April. Snyder made sense of this by noting that late April is a time when people emerge from a somewhat more dormant period of not exercising as much.

The team also observed that PER1, a gene responsible for circadian rhythms, had a seasonal pattern, with its highest expression in spring. Furthermore, other studies have found that PER1 may play a role in the development of cancer and that incidences of localised tumours appear to be highest in the spring. Snyder's team suggests that their observation of a spring peak for PER1 provides additional evidence that the gene may contribute in some way to cancer growth.

AN INDIVIDUAL APPROACH

So how could this research be useful? For a start, it will help us understand the fluctuations in the human body from patient to patient – variations that can't be measured in the tests we typically get when we visit the GP. But also, a standalone measure, such as a temperature reading, is often interpreted against a population average, without the context of the individual's normal, healthy baseline. For example, the average human temperature is 36.5°C, though even that varies by gender, age and throughout the day, according to a *Journal Of Internal Medicine* study. But an individual's 'normal' temperature may range from 36.1 to 37.2°C. A patient with a low baseline who registers a temperature that's towards the

WHAT IS MULTIOMICS?

RESEARCHERS IN THE FIELDS OF HEALTH AND BIOLOGY OFTEN USE THE SUFFIX -OMICS. BUT WHAT EXACTLY DOES IT MEAN?

-OMICS

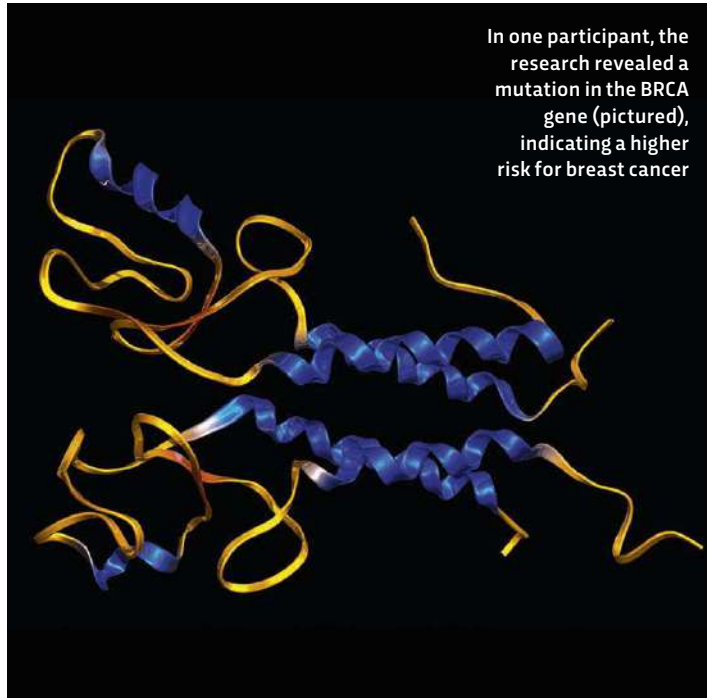
When added to a molecular or microbial term, the suffix '-omics' refers to the comprehensive analysis of a collection of those molecules or microbes. For example, genomics is the comprehensive study of all of an organism's genes. Genomics is different from genetics, which considers single genes or their variants.

Scientists often talk informally of 'omics' or 'omics groups', which may include genomics, metabolomics, proteomics, transcriptomics, epigenomics, microbiomics and others.

MULTIOMICS

Multimomics, which formed the basis of the study led by Prof Michael Snyder, is a branch of molecular biology in which researchers combine and analyse large data sets representing different omics groups. The goal of multimomics is to highlight relationships among the collections of molecules and their functions.

OMICS GROUP...	...IS THE COMPREHENSIVE ANALYSIS OF AN ORGANISM'S...	...WHICH IS A COMPLETE SET OF THE ORGANISM'S...
Genomics	genome	genetic material (genes), which contain instructions for building the organism
Metabolomics	metabolome	metabolites, which support the organism's metabolism
Proteomics	proteomes	proteins, which bind to molecules and perform specific tasks for cells
Transcriptomics	transcriptome	messenger ribonucleic acid (mRNA), which carry messages from deoxyribonucleic (DNA) to proteins, among other RNA
Epigenomics	epigenome	chemical changes to DNA and histone proteins
Microbiomics	microbiome	microbiota, including bacteria, viruses and fungi in a given community, such as a person's skin, gut or nasal passage



In one participant, the research revealed a mutation in the BRCA gene (pictured), indicating a higher risk for breast cancer

► high end of the normal range may indeed have a fever, even though the doctor taking that patient's temperature may not realise it.

"People usually go to the doctor when they're ill. They don't often go when they're healthy. We never take advantage of the longitudinal nature of data – collecting data over time. That's the essence of what we're trying to do," Snyder says.

Besides, an individual's temperature or other health metrics may vary over a given year, even when they're healthy. And disease markers for conditions such as arthritis, sleep disorders, and many neurological and psychiatric illnesses may also vary throughout the year. All of which raises questions about seasonal influences on health.

"If your cholesterol is higher in the winter than in the summer, is that normal biological variation or is that signifying a potential health problem?" asks Dr Laura Cox, professor of molecular medicine at Wake Forest School of Medicine, who was not involved in the study.

PERSONALISED HEALTH

Until nearly the end of the 20th Century, researchers did not understand the existence or usefulness of a multiomics approach to human biology. Instead, they conducted targeted studies that looked at the influence of a single gene or a single protein on health or disease.

In recent decades, however, multiomics such as genomics and proteomics (collections of genes or proteins, respectively) have allowed researchers to gain a more integrated understanding of biological impacts on health and disease. (Turn to p69 for brief explanations of these and other omics.)

"The genes and the proteins and the metabolites and the lipids are all talking to each other all the time," Cox



The study was carried out in the San Francisco Bay area, but the methods could be used for people in other regions

×

"If your cholesterol is higher in the winter than in the summer, is that normal biological variation or is that signifying a potential health problem?"



explains. By quantifying tens of thousands of these measurements in a deep longitudinal multiomics profile, researchers may then determine what is, and is not, likely to be biologically important.

Snyder's study offers personalised health models – one for each study participant – that follow and predict health trajectories. The models paint a picture of the normal biological variation in the different omics groups for the patient throughout the year, which is key in catching disease in its early stages.

Evidence supporting this approach is compelling. Snyder reports that the deep longitudinal multiomics profiles uncovered major health discoveries among nearly half of the participants, including early diagnoses of lymphoma, heart problems and a BRCA gene mutation indicating a high risk for breast cancer.

Snyder himself is a devout health logger. He even published results from his personalised omics profile in a 2012 paper in the journal *Nature Reviews Genetics* (he was both an author and the study's only participant). Today he wears

eight portable devices to track his daily health, including four smartwatches, a continuous glucose monitor, a meter that measures environmental exposures, a health tracker ring, and a pulse oximeter. Recently, his smartwatch and pulse oximeter indicated that his blood oxygen level had dropped at the same time that his heart rate had increased, which turned out to be the first indication of a forthcoming diagnosis of Lyme disease.

The seasonal study that Snyder and his team have carried out is a research version of personalised health medicine that represents deep profiling, but he accepts that it will be difficult to do for the entire population. "You're not going to do that for everybody. But we can try and figure out what's most useful and then try to put out a cheaper, higher utility, 'most bang-for-the-buck' version," Snyder says. He also mentions that his ultimate goal is to use big data to build personalised health models depicting trajectories for every single person on the planet.

Cox, who has no connection to Snyder, calls the study a "tour de force", as few others have studied as much multiomics data over such a long a period of time. "Often, we see a very brief snapshot in time and infer a whole, continuous timeline based on that one brief snapshot," she says. "It brings up: how much are we missing?"

PREVENTATIVE CARE

It's clear to see how tracking someone's every bodily fluid, microbe and molecule for four years would create a higher resolution picture of their health, and allow doctors to take preventative measures protect them from disease. Sadly, however, this won't be manageable in the real world. For a start, the culture of medicine would need to shift its focus from the current model of diagnosing and treating someone according to their symptoms, to focusing on early diagnostics and prevention. This is assuming that the high cost of comprehensively tracking everyone's health metrics – not to mention any privacy concerns – could be addressed.

Nonetheless, in revealing that, according to their biology, northern Californians experience two seasons rather than the traditional four we associate with the calendar, this research suggests that seasonal influences should be considered when addressing human health and disease management. Plus, the study offers a template for identifying seasonal counts and influences in other parts of the world, which may have an impact on our understanding of human health and disease management in those regions.

So how many seasons are there? Well, it's difficult to say for certain, but your health likely depends on the answer. "Even so," Snyder notes, "I predict that there aren't going to be four seasons with three months each." **SF**

by **SUSAN D'AGOSTINO**

Susan is a writer and mathematician. Her latest book is How To Free Your Inner Mathematician: Notes On Mathematics And Life (£25, Oxford University Press).

ASTRONOMY

A BEGINNER'S GUIDE TO





LOCKDOWN TURNED US INTO A NATION OF AMATEUR BAKERS, GARDENERS AND ASTRONOMERS. WHILE WE CAN'T HELP YOU WITH THE FIRST TWO, WE CAN HELP YOU CARRY A NEWFOUND PASSION FOR THE NIGHT SKY INTO 2021...

by **Abigail Beall**

You don't need lots of expensive equipment to see incredible things in the night sky. With just a bit of guidance, you'll soon be able to spot planets, stars, meteors, nebulae and even another galaxy. Throughout 2021, there will be plenty of opportunities to witness some wonderful cosmic sights, like the Andromeda Galaxy, located some 2.5 million light-years away. Here's what you need to know to get started...

DO I NEED TO BE OUTSIDE?

Not necessarily. There are plenty of beautiful views of otherworldly objects that you can see from the comfort of your house or car. The key is making sure you reduce the light around you as much as possible. If you want to stargaze from home, go to the highest window you have and turn off all the lights in your house. Wherever you are stargazing, it's important to give your eyes time to grow accustomed to the dark. After 15 minutes your eyes start to adjust and you'll see much more, but it takes about 40 minutes to fully adjust to the dark. Avoid using a torch or looking at your bright phone screen.

WHEN IS THE BEST TIME OF THE MONTH TO STARGAZE?

This depends on what you are looking for. If you want to study the Moon using binoculars, the best time to look is a few days before or after the full Moon, when the glare will not be as intense. But if you're looking for fainter objects, it's best to look when the Moon is as small as possible, so around the new Moon or when the Moon has set for the night (just before dawn). If you're struggling to see something, try looking away slightly and it might appear in the ☾



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help with your stargazing
bit.ly/stargazing-apps



A small telescope can aid with your stargazing, but is not an essential purchase

➤ corner of your eye. This is called 'averted vision', and it works because the centre of your eye is less sensitive than the bits around it.

DO I NEED TO BUY A TELESCOPE, OR A PAIR OF STARGAZING BINOCULARS?

There is no need to splash out on expensive equipment, especially when you're first getting into stargazing. There is so much you can see with the naked eye – planets, stars, satellites, meteor showers and the Moon. If you want to take your stargazing a little further, start with a pair of binoculars. The important thing with binoculars is magnification – binoculars with 10x magnification will let you see the craters on the Moon, the Galilean moons of Jupiter, and comets (when they're visible).

A small telescope, with 25x or 50x magnification, will let you see the rings around Saturn. Remember, the best telescope is the one you will use, so don't spend lots of money on something you won't bother getting out the box.

HOW CAN I TAKE BETTER PICTURES OF THE NIGHT SKY?

If you want to take photos of the sky using your smartphone, there are a few things you can do to improve their quality. Turn off the flash and don't use digital zoom. If you're using a digital camera, start with an ISO of around 100 and increase it to see what the noise or distortion is like.

The longer the shutter is open the more light you will let in, but if you leave the shutter open for more than 20 seconds the stars will blur – remember we are on a spinning rock! If you want to capture star trails, then you can go for a much slower shutter speed. But if you're looking to photograph deep sky objects, you will need to get a motorised mount that moves your camera to compensate for the rotation of the Earth.

HOW CAN I SEE A METEOR SHOWER?

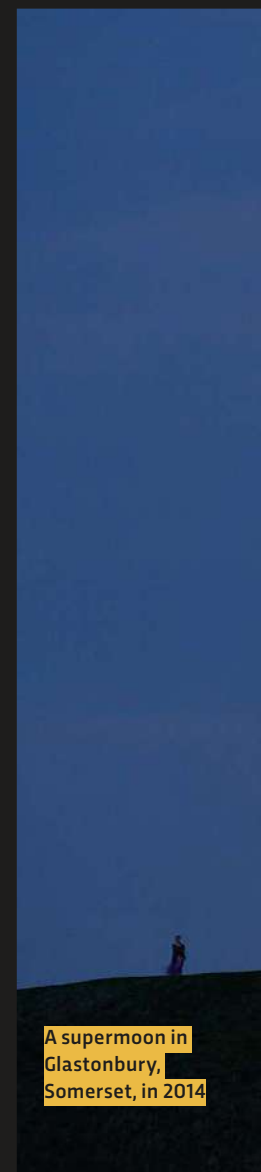
If you're stargazing for about an hour you will probably see a couple of meteors. But meteor showers only happen at certain times of the year, because they depend on where Earth is in its orbit around the Sun. Usually, meteor showers are best seen between midnight and sunrise.

WHAT THE DIFFERENCE BETWEEN A METEOR, AN ASTEROID AND A COMET?

A meteor is a flash of light caused by bits of dust or rock entering Earth's atmosphere and burning up. Meteors are usually caused by debris that has broken off an asteroid or a comet. An asteroid is a lump of rock originating in the asteroid belt between Mars and Jupiter. Comets are from much further away, and they contain lots of ices that are heated up when they come near the Sun, creating a large tail.



During a total lunar eclipse, the Moon takes on a reddish hue



A supermoon in Glastonbury, Somerset, in 2014



SHOOT FOR THE MOON

YOUR FIRST STEPS OBSERVING THE LUNAR SURFACE MAY FEEL LIKE A GIANT LEAP INTO THE UNKNOWN. HERE'S ALL THE INFORMATION YOU NEED TO SEE THE EARTH'S NEAREST NEIGHBOUR AT ITS BEST

HOW CAN I SEE A SUPERMOON?

The Moon doesn't orbit Earth in a circle – it has an elliptical orbit. This means the distance between the Earth and the Moon varies. The closest point in the orbit is called perigee and the furthest away point is apogee. When a full Moon happens at the same time the Moon is closest to the Earth – less than 360,000km (223,694 miles) away – this is a supermoon. The next supermoon will be on 28 March 2021.

HOW CAN I PHOTOGRAPH THE MOON AT NIGHT?

To capture the Moon with your phone, you might need to play around with your camera settings. Don't use a flash, turn down the ISO and set your focus to 100. If you are unsure how to make these changes, download a night photography app (such as *NightCap*) which will allow you greater control over the camera settings than your usual camera app.

If you're using a digital camera, start with an aperture of f/11 to f/16 and a shutter speed of between 1/60th and 1/125th of a second. A tripod will help keep your camera still and reduce any shaking from the low light conditions when you need to keep the shutter open a little longer.

To get the best pictures of the Moon you need to work out your shot, making sure you can frame the Moon depending on the scenery around you. To plan where you can see the Moon, or anything in the night sky, there is plenty of software available (like the *Moon Locator* app).

DOES THE MOON ROTATE?

Yes, the Moon is rotating. But it is tidally locked, which means it rotates in sync with its orbit of the Earth, so for every orbit of the Earth it completes one rotation. This means as it travels around our planet, the same side faces us the whole time. This is why we have the term 'dark side of the Moon', for the side we never see. In reality, that side of the Moon gets just as much sunlight as the side we see, so the correct term is the 'far side of the Moon'.

WHAT IS A BLOOD MOON AND HOW CAN I SEE IT?

During a total lunar eclipse, the Moon turns a red colour because Earth's atmosphere scatters blue light away and only the red gets through. This is called a blood Moon. The next blood Moon is happening on 26 May 2021.



YOUR FIRST NIGHT: WHA

ONCE YOU'RE SET UP, WHAT CAN YOU ACTUALLY OBSERVE ON AN AVERAGE EVENING? USING THE INSTRUCTIONS

URSA MAJOR

The constellation of Ursa Major is visible from most parts of the northern hemisphere all night, all year round. It's easy to spot using the asterism known as the Plough in the UK. Always near the general direction of north, the Plough is recognisable by the three stars in its 'handle', and four in its 'bowl'. From this asterism you can find lots of different things in the sky.



ORION

Another easily recognisable constellation is Orion, which you can find using the three stars that make up Orion's Belt. Orion is a winter constellation in the northern hemisphere. Orion will be visible as soon as the Sun sets, the constellation will then dip below the horizon in the early hours of the morning. If you look slightly below Orion's Belt, you'll see a fuzzy patch which is the Orion Nebula. Through binoculars or a telescope this looks incredible.



ARCTURUS

From the Plough, a really simple star hop, and an easy one to remember, is following the arc of the handle to the star Arcturus. Draw an imaginary line from the star closest to the bowl, through the others in the handle, and keep going until you see a bright star. Arcturus is a bright star in the constellation Boötes, and is the fourth-brightest star in the night sky.



THE PLEIADES

The Pleiades, or Seven Sisters, is a cluster of stars in the constellation Taurus. Look for Orion's Belt, then follow the stars from left to right. Keep that line going, and you'll get to a bright star called Aldebaran, the brightest in Taurus. Go a little further, and you will see a small cluster of stars that almost looks like a tiny version of the Plough. That is the Seven Sisters.



THE NORTH STAR

Polaris, or the North Star, is always visible in the northern hemisphere, and unlike all other stars, it doesn't move. You can use the Plough to find the North Star. If you imagine the Plough is like a pan with a handle, with its base at the bottom, find the two stars furthest from the handle, these are called Merak and Dubhe. Draw a line from bottom to top, keep that going and you'll get to Polaris.



SIRIUS

Sirius, or the dog star, is the brightest star in the night sky. It's bright because it's close – only 8.6 light-years away – and it's actually a binary star (two stars orbiting each other). To find Sirius, you can use Orion. The three stars in Orion's Belt act as a pointer to Sirius. In the northern hemisphere, follow the stars from right to left, then keep that line going until you find the brightest star.



T TO LOOK FOR

BELOW, SEE HOW MANY CELESTIAL LANDMARKS YOU CAN SPOT

by **ABIGAIL BEALL**

*Abigail is a freelance science and space journalist. Her latest book is *The Art Of Urban Astronomy: A Guide To Stargazing Wherever You Are* (£12.99, Trapeze).*

CASSIOPEIA

Another constellation visible from most of the northern hemisphere all year round is Cassiopeia. This is a small constellation that circles the North Star, making a W or M shape depending on the time of night. If you found Polaris using the Plough, follow that line again and keep it going until you see the recognisable form of Cassiopeia.



MARS

Occasionally appearing as one of the brightest planets, Mars shines with a distinctive reddish hue. As with all planets, Mars is on its own orbit of the Sun, so its position in the sky changes. By using any stargazing app, you'll be able to plan when to see Mars.



ANDROMEDA GALAXY

From Cassiopeia, you can star-hop to one of the most distant things you will ever see with your eyes. The Andromeda Galaxy, also known as M31, is a spiral galaxy 2.5 million light-years away, and you can see it with the naked eye. Using Cassiopeia, find the deepest of its two V-shapes. This acts as an arrow pointing you to Andromeda, which will look like a fuzzy patch in the sky (appearing slightly clearer through binoculars or a telescope).



JUPITER

Far across the Solar System, Jupiter shines brightly in the sky because of its sheer size. When visible, it is one of the brightest objects in the night sky. Throughout January it will set and rise with the Sun, meaning we won't be able to see it. It won't be visible again until the end of April, when it starts to rise before the Sun. If you look through binoculars, you'll be able to see four of Jupiter's moons.



SATURN

Smaller and further away than Jupiter, Saturn is not as bright as its gas giant neighbour, but can still be seen from light-polluted cities. Like Jupiter, however, it won't be visible until mid-April when it starts to rise before the Sun, at around 4am. If you have a small telescope, you'll be able to see Saturn's rings and some of its moons.



THE INTERNATIONAL SPACE STATION

The ISS is the brightest satellite, making it easy to spot in the night sky. When it's visible, it looks like a solid white light moving quite quickly across the sky, usually crossing in a couple of minutes. It tends to be visible just before sunrise or just after sunset. The best way to find it is to sign up to NASA's Spot the Station service, which will tell you exactly when it'll be visible in your area.

FROM THE MAKERS OF

BBC **Science Focus**

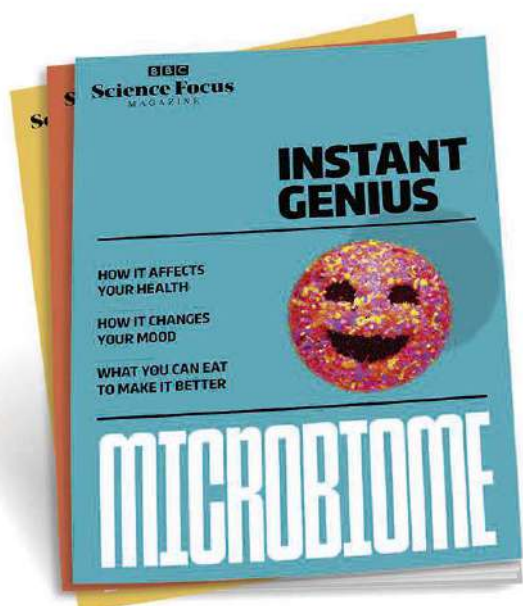
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Q&A

YOUR QUESTIONS ANSWERED

... WHY WERE SO MANY MISSIONS TO MARS LAUNCHED LAST SUMMER?
 ... COULD WE SURVIVE ON BEER ALONE?
 ... WHAT MAKES SPIDER SILK SO STRONG?
 ... HOW CAN WE TELL THAT A METEORITE HAS COME FROM A PARTICULAR PLANET?
 ... WHAT IS CONSCIOUSNESS?
 ... WHY DO SOME BIRDS HOP AND OTHERS WALK?
 ... COULD THERE BE FOSSILS ON MARS?
 ... COULD A PLANET ORBIT BACKWARDS, IN RELATION TO OTHER PLANETS IN A SOLAR SYSTEM?
 ... WHY WERE THE DINOSAURS SO SUCCESSFUL?

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 Palaeontologist and biologist

LUIS VILLAZON
 Science and technology writer



LARA HOPKINS, LONDON

IS FISH 'BRAIN FOOD'?

We've all read or heard that eating fish is good for your brain. Indeed, a large study in 2008 hit the headlines when it claimed that eating oily fish can reduce the harmful brain lesions that are associated with Alzheimer's disease.

But do these claims stand up to scrutiny? A good source of information are Cochrane Reviews, which independently analyse all the available evidence to inform healthcare decision-making. And the evidence for oily fish and its impact on the brain isn't convincing. For example, a 2012 Cochrane Review showed that fish oils made no difference in preventing dementia. A similar Cochrane Review in 2016 found that fish oils also made no difference for people who

already had Alzheimer's disease. What about depression? Unfortunately, a 2015 Cochrane Review found that more evidence was needed as to whether fish oils have any benefit.

So it looks like there is little hard evidence that oily fish improves cognitive function, protects against conditions such as dementia, or helps people with depression. However, some studies have shown a benefit in mice, so maybe more research is needed.

Nonetheless, the NHS still recommends eating oily fish as part of a healthy diet, because it is likely to have some positive health benefits, including reducing the risk of heart disease. **NM**

ILLUSTRATION: DANIEL BRIGHT

TOP 10... HAPPIEST COUNTRIES

SOURCE: [WORLDHAPPINESS.REPORT/ED/2020/](#)

The scores, which were compiled as part of a Gallup World Poll, are based on individuals' assessments of their subjective wellbeing. The poll asks respondents to rank their lives, from 0 to 10, with 10 being the best possible life they could have, and 0 being the worst. Countries at the top of the table have high levels of variables that support wellbeing, such as income, healthy life expectancy, generosity and freedom. With a score of 2.567, Afghanistan is the world's least happy country. **HP**



10. LUXEMBOURG
(7.238)



5. NORWAY
(7.488)



9. AUSTRIA
(7.294)



4. ICELAND
(7.504)



8. NEW ZEALAND
(7.300)



3. SWITZERLAND
(7.560)



7. SWEDEN
(7.353)



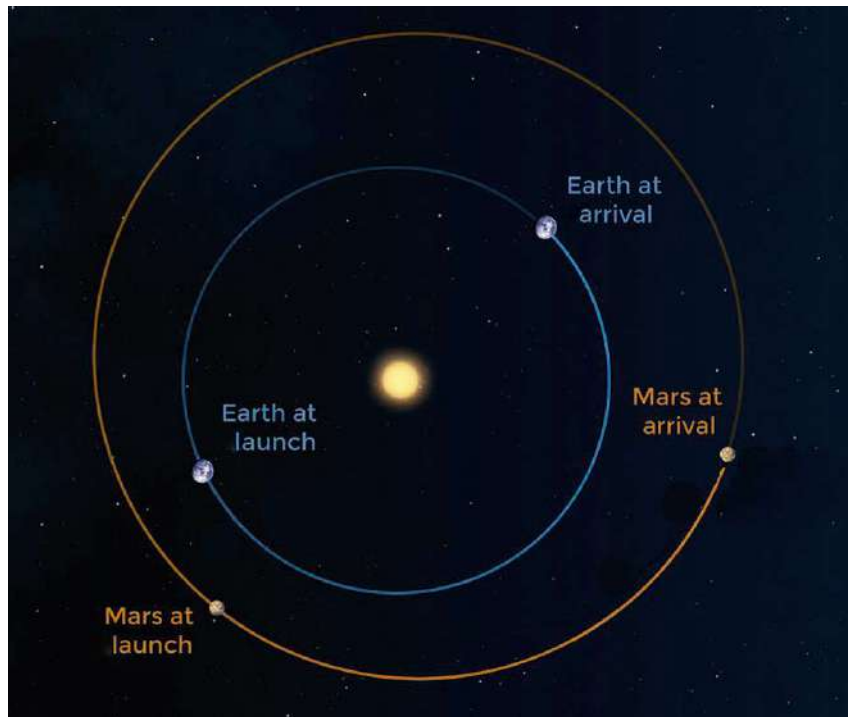
2. DENMARK
(7.646)



6. NETHERLANDS
(7.449)



1. FINLAND
(7.809)



ANDREW BLACK, VIA EMAIL

WHY WERE THERE SO MANY MISSIONS TO MARS LAUNCHED LAST SUMMER?

July 2020 was a particularly busy month for space agencies. Three missions were launched to the Red Planet: the Emirates Mars Mission, China's Tianwen-1, and NASA's Mars 2020 mission. (ESA's ExoMars probe launch was postponed until 2022.) All three probes are arriving this February. But why were there so many leaving Earth at one time? The reason was the so-called 'Hohmann transfer orbit'.

To journey from Earth to Mars, a spacecraft is launched into an elliptical orbit. To save fuel (and time), the best 'launch window' occurs when the path between the two planets is at a minimum. This happens around the time that Earth and Mars line up with the Sun. This is known as 'opposition', because Mars is then exactly opposite the Sun in the sky. This alignment happens every 26 months or so. To take advantage of this particular planetary alignment, the missions needed to start in July 2020 and end this February, minimising the distance each probe has to travel. Other factors, such as the capability of the launch vehicle, the mass of the spacecraft and the desired time of arrival at Mars also help determine the exact launch date. **AG**

WENDY REYNOLDS, CAMBRIDGE

COULD DARK MATTER HAVE EXISTED BEFORE THE BIG BANG?

Most theories explaining dark matter hypothesise the creation of particles after the Big Bang. However, the Big Bang did not mark the beginning of space and time. One theory, mostly confirmed by observation, suggests that before the Big Bang,

CASSANDRA STURGEON DELIA

COULD WE SURVIVE ON BEER ALONE?

It is not possible to survive indefinitely on beer alone. The drink contains water and sugar, along with some vitamins and minerals, but is deficient in other nutrients needed for the body to function properly, including protein, fat and thiamine (vitamin B1). It contains little or no vitamin C. With an average pint of beer containing around 240 calories, you would need at least eight pints per day to fuel the body. Over time, the high volume of alcohol would harm your liver and kidneys. Alcohol is a diuretic, so dehydration could also be an issue. **ED**



during a phase of 'cosmic inflation', there was nothing in the Universe except an energy field. It is possible that dark matter originates during this period of inflation. If so, its signature should be imprinted on the distribution of matter in the Universe. **AG**



DEAR DOCTOR...

DELICATE ISSUES
DEALT WITH BY
SCIENCE FOCUS EXPERTS

WHY IS MY WIFE ALWAYS COMPLAINING THAT THE HOUSE IS TOO COLD?

There are some studies that claim that women feel colder than men. For example, in 2015, a widely reported study by two Dutch scientists suggested that women are comfortable at a temperature 2.5°C warmer than men. But their sample size was small, and other studies have shown no difference between the sexes.

That hasn't stopped theories emerging as to why women might feel colder. Some have suggested that women's blood vessels shut down sooner and for longer compared to men in response to the cold, possibly because they have more oestrogen. Others claim that women produce less heat because they have a lower

metabolic rate (the rate of energy expenditure per unit of time). Another theory is that women have more fat than men, and this insulates the skin so their skin temperature is lower.

None of the evidence is entirely convincing. In truth, we are more likely to hear about evidence that explains why women might feel colder because it's more interesting to read. The real reason that women prefer higher ambient temperatures than men may simply be explained by the lighter clothing normally worn by women.

Your wife might simply be complaining that it's too cold because we all experience temperatures differently. **NM**



FAYE LYNCH WILLIAMS (AGE 15), VIA EMAIL

WHAT IS CONSCIOUSNESS?

From a medical perspective, consciousness is a description of our current level of awareness: people who are fully awake are completely conscious but, at the other extreme, people in a coma are without consciousness because they have no subjective thoughts or sense of awareness. Other states of consciousness, such as sleep and intoxication, sit between the two – awareness and subjective clarity are diminished but not completely absent.

From a philosophical perspective, consciousness is hard to define. Usually what is meant by the term is 'phenomenological consciousness' – a subjective feeling of what it is like to be that person or thing. Philosophers call these subjective conscious experiences 'qualia' (examples would be the redness of red and the bitterness of coffee). They are tricky for scientists to investigate, as we can never truly know if another person is having a subjective conscious experience.

Neuroscientists still don't agree on how the human brain gives rise to a subjective sense of consciousness. One popular theory – the global neuronal workspace theory – likens the mind to a theatre, and proposes that when something becomes the focus of our attentional 'spotlight', this leads to a spread of neural activity beyond purely sensory processing areas, allowing the information or experience to reach the level of conscious experience. **q**



CROWDSCIENCE

Every week on BBC World Service, *CrowdScience* answers listeners' questions on life, Earth and the Universe. Tune in every Friday evening on BBC World Service, or catch up online at bbcworldservice.com/crowdscience



ARE HUMANS NATURALLY CLEAN AND TIDY CREATURES?

Thousands of years ago, our ancestors were already using latrines and tidying their hair with combs, suggesting we have some deep-rooted tidy tendencies. Yet people today still engage in gross habits, such as eating lunch over a keyboard or failing to wash their hands after visiting the loo. The reason for these contradictions is that our natural inclination for cleanliness and good hygiene isn't borne from reason, but driven by our sense of disgust. This emotion protects us from the risk of infection, but it's far from foolproof or logical – it's triggered by certain sights, smells and beliefs, rather than any objective measure of hygiene. Generally speaking, people are more bothered by dirt they can see and smell, even if it's harmless, rather than germs that are invisible, even if more deadly.

The evolutionary roots of our instinct for cleanliness – as a way to protect ourselves from disease – explains other paradoxes. We might wipe down our own kitchen surfaces with antibacterial cleaner, yet collectively we fill the oceans with plastic.

Looking across the animal kingdom, we've no reason to be smug. Not only do other creatures also show an inclination for being clean (birds keep nests clear of faecal matter, and bees remove their dead from the hive), but often they outdo us. Research by ecologists at North Carolina State University showed that, while human beds are filled with bacteria derived from our own bodies, this was much less the case with chimpanzees – probably because they go to the trouble of making a new treetop bed each night. **q**



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MATTHEW TANG

WHAT MAKES SPIDER SILK SO STRONG?

Spider silk has a complex structure that gives it strength. Robust crystalline structures are linked together by stretchy formations which together create something that's flexible and firm. In 2018, researchers also found that spider silk is woven from thousands of parallel strands, 20 nanometres across. Just like the strands in a rope, this distributes the load, preventing critical stresses from snapping the silk. Spider silk can stretch five times its length without snapping. **LV**

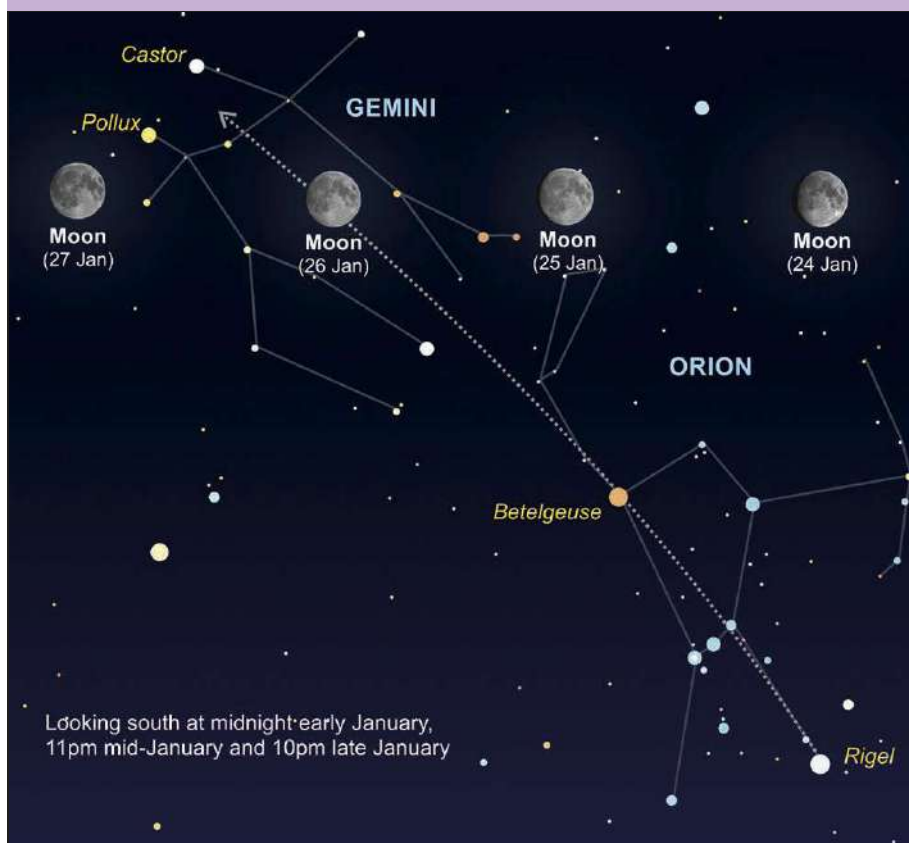
RODNEY MINNS, LIPHOOK, HAMPSHIRE

HOW CAN WE TELL THAT A METEORITE HAS COME FROM A PARTICULAR PLANET?

Rocks, including meteorites, can be dated by looking at the ratios of certain radioactive isotopes (a method analogous to 'radiocarbon dating'). Most meteorites turn out to be about 4.56 billion years old, because they come from asteroids that date from the creation of the Solar System. Anything younger must be from a planet or moon. Scientists have found that the ratios of oxygen isotopes in meteorites are different for each parent body. Furthermore, some meteorites are found to have trapped gases whose isotopic composition exactly matches what has been measured for the atmosphere on a particular planet. Together, these strands of evidence make the origin of most meteorites pretty certain. **AG**



ASTRONOMY FOR BEGINNERS



Looking south at midnight: early January, 11pm mid-January and 10pm late January

HOW DO I SPOT GEMINI?

WHEN: JANUARY TO MARCH

The constellation of Gemini is one of the few that actually looks like what it represents: a pair of twins. Once you know how to spot them, the twins – with their two brightest stars Castor and Pollux – are easy to see from most parts of the world.

Gemini is one of the 13 zodiacal constellations, defined by where they sit in the sky. These constellations all sit within an imaginary line in the sky called the ecliptic, which is the path the Sun traces across the sky in a year. In the northern hemisphere, Gemini is visible all night from January to March, but can be seen until May. This makes January and February, with their long, dark nights, a great time to find it.

To find Gemini, we start at Orion. This constellation is one of the easiest to spot, with the three stars in a row making up Orion's Belt. In the northern hemisphere during January and

February, Orion will be in the southern sky if you look at 9pm, getting more western as the night goes on.

The two brightest stars in Orion are Betelgeuse, its red-looking left shoulder, found above the belt, and Rigel, its blue-hued right leg, below the belt. To find Gemini, draw an imaginary line from Rigel through Betelgeuse, and carry this on. When you get to two bright stars close together, you have found Castor and Pollux.

These two bright stars represent the heads of the twins, so once you've found Castor and Pollux, you should be able to spot the rest of the constellation, which sits between the pair of stars and Orion.

If you don't want to star-hop, you can use the Moon to find Gemini, but only on the 27 January. On this day, the Moon will be right next to the twin stars for most of the evening. **AB**

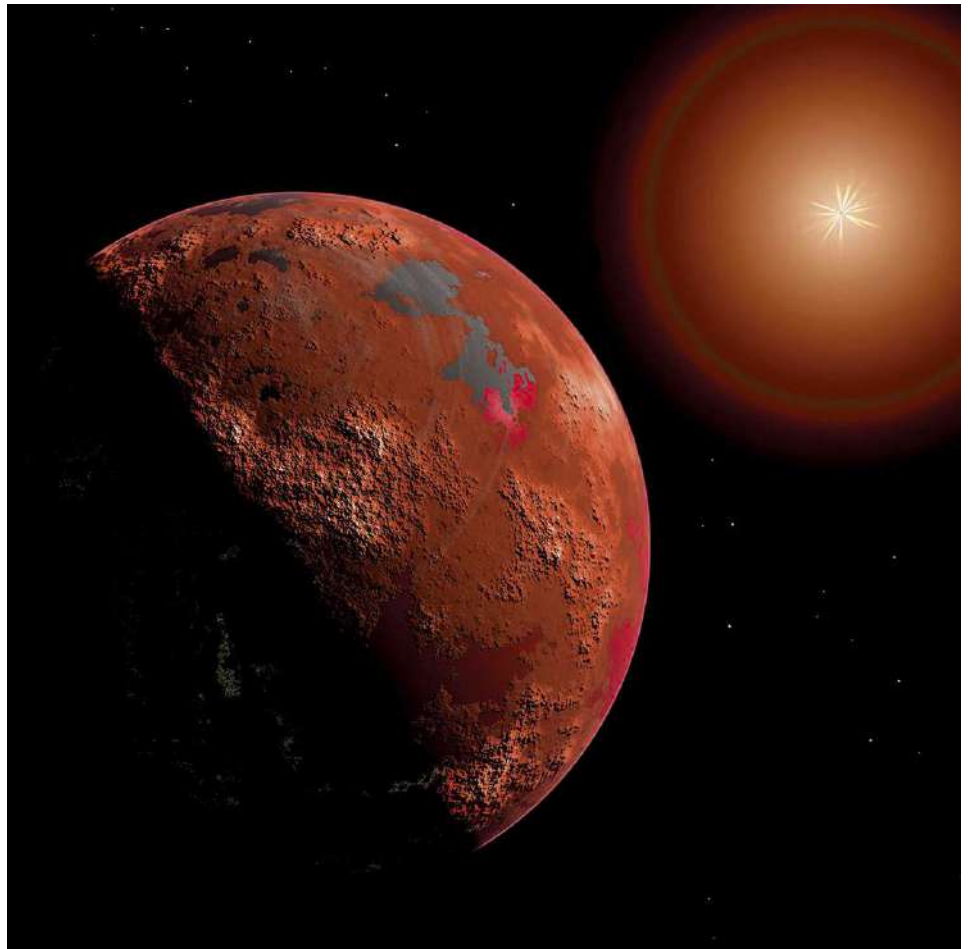
GARY THEOBALD

WILL SOCIAL DISTANCING MEASURES CAUSE CORONAVIRUS TO EVOLVE INTO A MORE DEADLY STRAIN?



Viruses, like COVID-19, evolve rapidly. Each time the virus replicates, mutations can occur in its genome. Most of these mutations have no effect, or are even damaging to the virus. However, occasionally a mutation will arise that is advantageous for the virus. These mutations may allow the virus to grow faster, spread better or evade our immune system. The longer a virus continues to circulate, the greater the chance of these mutations occurring and the virus evolving into a new strain that behaves differently. However, causing more severe disease isn't necessarily advantageous to the virus. One of the reasons the COVID-19 virus is so difficult to contain is that it spreads very well before people become sick. If the virus spreads while causing more severe symptoms, people with COVID-19 would likely stay home instead of going out (reducing transmission) and would seek medical attention (enabling more effective testing and contact tracing). Sometimes mild viruses are the most difficult to eliminate.

Because the COVID-19 pandemic has been so difficult to contain, we have all had to take precautions, such as social distancing, washing hands and wearing masks. Each of these individual precautions limits the amount of virus that can spread from one person to another. These actions could put pressure on the virus to evolve, possibly resulting in mutated strains that are more transmissible and more difficult to control (though not necessarily deadlier). However, by combining all of these precautions, together with strong public health infrastructure (such as test and trace), we can still effectively stop the transmission of COVID-19, even if it evolves into a more virulent strain. **JR**



PAUL LAYFIELD

CAN A PLANET ORBIT BACKWARDS COMPARED TO THE OTHER PLANETS IN A SOLAR SYSTEM?

All of the planets in the Solar System orbit the Sun in the same direction as the Sun's rotation, i.e. anticlockwise, looking from above the Sun's north pole. These are known as 'prograde' orbits (literally 'moving forwards'). Their direction is a consequence of the initial rotation of the cloud of gas and dust from which the Sun and planets formed. A planet with a 'retrograde' orbit, i.e. moving in the opposite direction to its home star's rotation, would require a massive change in energy to reverse its initial prograde orbit, and this is why planets with retrograde orbits are rare. (Retrograde orbits are more common with comets and asteroids, because they're smaller and easier to move out of their original orbits.)

But retrograde planets do exist – two examples are the exoplanets Kepler-2b

and WASP-17b. The process responsible may be what's known as the 'Kozai mechanism', in which the gravitational effect of a distant third body can cause a perturbation in a planet's orbit that slowly moves the planet into a tilted and elongated orbit. This tilt eventually becomes so extreme that the orbit is flipped over. Another possible mechanism for reversing a planet's orbit is the gravitational effect of a close encounter or collision with a large body. However, most of these interactions would likely destroy the planet completely, or at least expel it from the star system. It's also possible that a star's disc of gas and dust, from which its planets form, can itself be flipped over if the disc strays too close to another clump of matter. Any planets formed in that disc would then have retrograde orbits. **AGu**



G O'Rourke

WHY DO SOME BIRDS HOP AND OTHERS WALK?

Birds that spend most of their time in trees tend to hop because this is faster and easier on narrow twigs and branches than walking like a tightrope acrobat. These birds have evolved legs and feet that hop efficiently, so it makes sense to keep this up even when they are foraging on the ground.

Hopping works best for small, lightweight birds with short legs. Each hop takes them as far as several steps if they were walking normally, so they use less energy. But even though it beats walking, hopping is slower than running. Blackbirds, for example, will switch from hopping to running if they are in a hurry.

Birds that belong to the same group usually share the same way of moving around, but this isn't always the case. In

the corvid family, for example, crows, ravens and magpies all walk, but jays hop.

Birds that nest and forage on the ground are much more likely to run than hop. This includes all the game birds like pheasants and grouse, but also smaller birds, such as wagtails, that chase insects on the ground.

Birds that forage along the seashore or estuary have often evolved long legs for wading that allow them to cover a lot of ground efficiently with each stride. It would be quite impractical for them to hop on such spindly legs. Another shorebird, the sandpiper, runs despite its relatively short legs. This allows it to forage very close to the water's edge and still outrun the incoming waves. **LV**

QUESTION OF THE MONTH

EMILY HUNTER, LEICESTER

COULD THERE BE FOSSILS ON MARS?

If life ever existed on Mars, and was of a form that could leave fossilised impressions, there is every reason to suppose that fossils exist on Mars. As yet, there is no evidence at all that life has ever existed on the Red Planet. (A key ingredient for life, water, does exist in the form of ice.) In 1996, a team of scientists claimed to have found evidence of fossilised bacteria in a fragment of Martian meteorite, but the claim was later rejected. Although NASA's Perseverance rover, about to arrive at Mars, is designed to look for chemical traces of life, it is not equipped to find fossilised remains. That will require a sample return mission. **AG**

WINNER

Emily wins a **JBuds Air Sport True Wireless Earbuds**, worth £70. With 40 hours of playtime, these sweat-proof earbuds have touch control and come with 'be aware audio', which lets in ambient noise to keep you safe while running outside. jlabaudio.com



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THE EXPLAINER

WHY WERE THE DINOSAURS SO SUCCESSFUL?



HOW SUCCESSFUL WERE THE DINOSAURS?

By every objective measure, dinosaurs were hugely successful. During much of the Mesozoic Era (252–66 million years ago), they dominated ecosystems on land, living in every conceivable environment from the poles to the equator, and from the seashore to the river valleys to the deep mountains. They diversified into thousands of species, ranging in size from feisty carnivores like *Microaptor* (about the size of a crow) to behemoth plant-eaters like *Brontosaurus*, with the heft of a jet aeroplane. Some were specialised runners, others diggers, and some even glided and flew. Some species were covered in armour and spikes, others had endless varieties of horns and crests for display, many lived in groups and had big brains and keen senses, and it seems like many dinosaurs – if not all of them – were covered in some type of feather. Indeed, today's birds evolved from dinosaurs, meaning that 10,000-plus species live on, continuing dinosaur success to the present day.



WHAT WERE THE FIRST DINOS LIKE?

Dinosaurs evolved in the Triassic, which began around 252 million years ago, after the most severe mass extinction in Earth's history. Massive volcanic eruptions in Siberia led to runaway global warming, which killed up to 95 per cent of all species. Among the survivors were small, cat-sized reptiles that could run fast. These dinosaur-like reptiles were the ancestors of dinosaurs. Around 230 million years ago, they gave rise to true dinosaurs, which are distinguished by their upright legs that fit into a window-like opening in the pelvis, which is attached to the backbone by extra vertebrae. These features allowed the first dinosaurs – like *Eoraptor* and *Herrerasaurus* – to run faster, cover larger distances, and expend less energy than most other animals of the time. These first dinosaurs diversified and split into the three fundamental divisions of the dinosaur family tree: the carnivorous theropods, long-necked sauropods, and beaked, plant-munching ornithischians.



HOW DID THE EARLIEST DINOSAURS BEAT THEIR RIVALS?

The first dinosaurs didn't take over the world right away. Rather, it took them more than 30 million years to assert their dominance. They were evolving in a world very different from today, as all land was joined into the supercontinent Pangea, which stretched from pole to pole. Sharing this landmass were early crocodiles and their relatives, which were the main competitors of the early dinosaurs. For most of the Triassic, the crocs were pulling ahead of the dinosaurs: there were more species of them, they had a greater richness of body sizes, diets and behaviours, and they lived across a broader range of Pangea. But just when it looked like the crocs were poised to defeat the dinosaurs, Pangea began to split, around 200 million years ago. Volcanoes erupted with gusto, spewing out greenhouse gases, causing global warming and another mass extinction. The crocs were decimated, but the dinosaurs survived nearly unscathed.

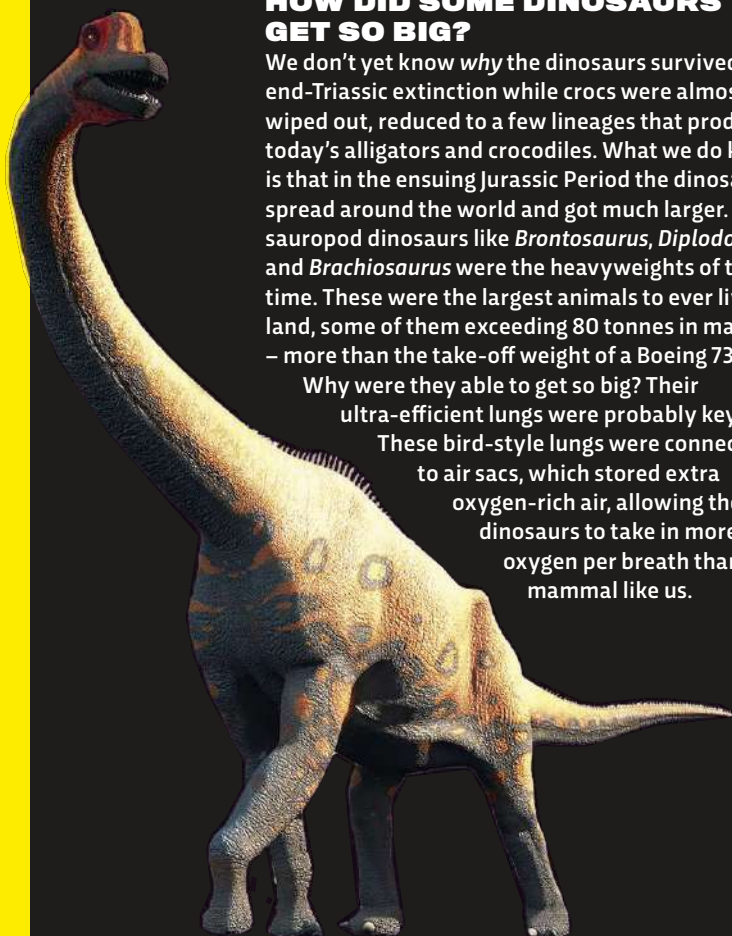


HOW DID SOME DINOSAURS GET SO BIG?

We don't yet know *why* the dinosaurs survived the end-Triassic extinction while crocs were almost wiped out, reduced to a few lineages that produced today's alligators and crocodiles. What we do know is that in the ensuing Jurassic Period the dinosaurs spread around the world and got much larger. The sauropod dinosaurs like *Brontosaurus*, *Diplodocus* and *Brachiosaurus* were the heavyweights of the time. These were the largest animals to ever live on land, some of them exceeding 80 tonnes in mass – more than the take-off weight of a Boeing 737.

Why were they able to get so big? Their ultra-efficient lungs were probably key.

These bird-style lungs were connected to air sacs, which stored extra oxygen-rich air, allowing these dinosaurs to take in more oxygen per breath than a mammal like us.



HOW DID THEY BECOME AIRBORNE?

Not all dinosaurs were enormous. One group, the paravian theropods, went in the opposite direction. Like most dinosaurs, the first paravians sported simple, hair-like feathers, which probably helped to keep them warm. As the paravians got smaller over time, the feathers on their bodies became larger and more packed together. Then they began to line up their feathers on their arms, to form wings. These first wings were too small to keep these dinosaurs aloft; instead, they were probably used for display. At some point, though, a threshold was crossed. The wings became big enough that, when flapped, they could provide a bit of lift and thrust, and keep these paravians airborne. Flight had evolved! From these flapping ancestors arose today's birds. In other words, birds *are* dinosaurs! So while *Triceratops*, *T. rex* and the other famous dinosaurs went extinct 66 million years ago, some dinosaurs live on.

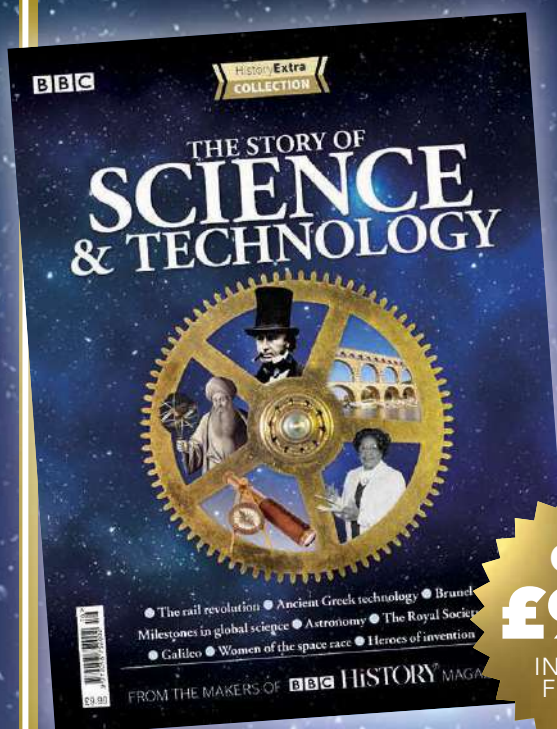
by **PROF STEVE BRUSATTE**

Steve is a palaeontologist at the University of Edinburgh and author of *The Rise And Fall Of The Dinosaurs* (£9.99, Picador).

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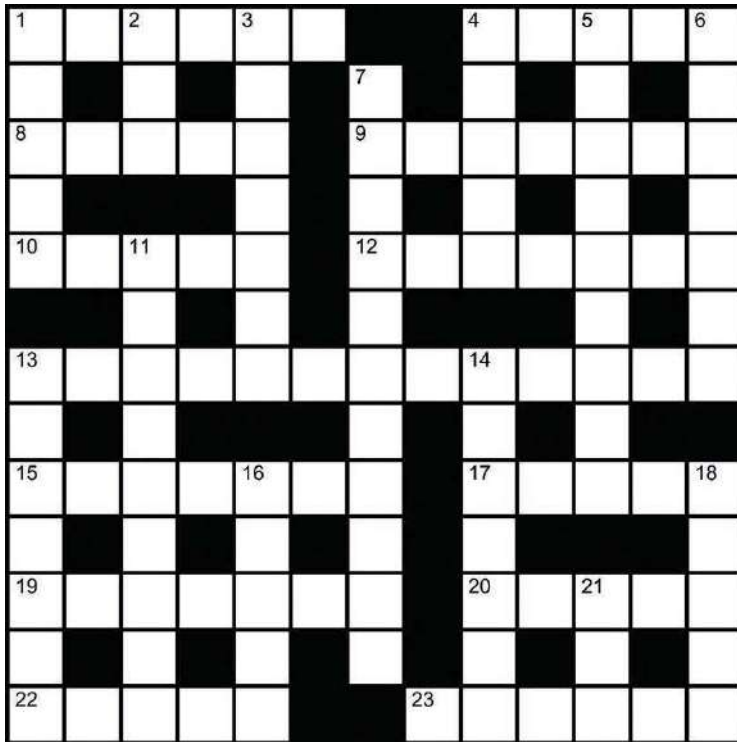
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GIVE YOUR BRAIN A WORKOUT



ACROSS

- 1 Blue-collar handbook (6)
 4 Organised tour around Edward's second house (5)
 8 Show indifference to a short jacket (5)
 9 Swears about acquiring new pain (7)
 10 Rich performance includes old singers (5)
 12 Fruit set out to be most unattractive (7)
 13 Honestly blond – also old-fashioned (4,3,6)
 15 Tribe getting a knock and a laugh (7)
 17 Tree, thinner on top? No top! (5)
 19 Motoring obstacle gives elegant article energy (7)
 20 Robber starts to take hostages in every fraud (5)
 22 Sheet of glass left on board (5)
 23 Immediately make amends, getting cold (2,4)

DOWN

- 1 Art form has inspiring figure endlessly in charge (5)
 2 And not out of ignorance (3)
 3 Country brewed lager with excellent backing (7)
 4 Draw the Spanish bathroom accessory (5)
 5 Owing new warder expected compensation (3,6)
 6 Ready, during routine, for award (7)
 7 Reason to report on spreading plants (6,5)
 11 Old and cross, treating an idiot for loss of hydrogen (9)
 13 Fixed limit on headgear (4,3)
 14 Group has a lot to drink with alien (7)
 16 Use a shroud, by the sound of it (5)
 18 Search for a firearm (5)
 21 Trendy name for a pub (3)

ANSWERS

For the answers, visit bit.ly/BBCFocusCW
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SF

A SCIENTIST'S GUIDE TO LIFE

HOW TO CONCENTRATE

THIS MONTH, WE TACKLE... OH, HANG ON, WAIT A MINUTE, I JUST NEED TO LET THE DOG OUT, NOW WHAT WAS IT AGAIN? PSYCHOLOGIST **DR NICK PERHAM** FROM CARDIFF METROPOLITAN UNIVERSITY EXPLAINS HOW TO CONCENTRATE

DISTRACTION ISN'T ALL BAD.

If we get distracted at work, it's not great for productivity, but distraction has a positive side. If we were always so focused that we never got distracted, we'd miss potential changes, such as threats, in our environment. Imagine if you were concentrating so hard on a book that you didn't hear a fire alarm going off. Distraction is vital for survival.

SILENCE IS BEST.

Of course, there are plenty of times when you do need to concentrate and noise becomes a problem. For example, we've found that people do worse on tasks such as mental arithmetic when there's background noise to disturb them.

SOME SOUNDS ARE MORE DISTRACTING THAN OTHERS.

Complex noises that are acoustically varied are more distracting than less varied sounds. We found that office noise with speech is more distracting than office noise without speech. Similarly, music with lyrics is more distracting than instrumental music.

BUT SOME PEOPLE SAY MUSIC HELPS THEM TO CONCENTRATE?

They may say this, but our research doesn't always back it up. If you ask

people to predict how well they'll do on a task while listening to music that they like, versus listening to music that they don't like, they tend to overestimate how well they subsequently do. Liked and disliked music tend to impair performance equally.

TRY WORKING IN A COFFEE SHOP.

Unless someone smashes a cup or makes some other sudden noise, the gentle background hum can feel like a pleasant backdrop for work. Similarly, noise-cancelling headphones seem to work because they screen out loud and unexpected sounds.

HAS LOCKDOWN IMPAIRED OUR CONCENTRATION?

Maybe. For people with busy households, there may be more distractions when working from home, but it's too soon to say if there is any long-term effect on concentration. It could just be that we are still adjusting to new ways of working in different environments.

LEARN TO CONCENTRATE BETTER.

There's an enormous amount of variation in people's ability to concentrate. Those with better working memory – the ability to store and manipulate information short term – seem to do best, but we can all improve by practising certain tasks that involve working memory. For example, try to remember and recall a list of, say, five numbers in order. Then the next week, try to remember six in order, then seven, and so on.

TURN OFF THOSE NOTIFICATIONS.

If you want to concentrate for a long time, don't make life unnecessarily hard. Turn off those notifications on your phone, or switch the phone off. Have a coffee. Take regular breaks, and let's hope that you're concentrating on something interesting. It's easy for the mind to wander when the subject matter is boring! **SF**

**DR NICK
PERHAM**

Nick is a senior lecturer in the department of applied psychology at Cardiff Metropolitan University. He researches auditory distraction, emotion and cognition.

**Interviewed by
Dr Helen Pilcher.**

NEED TO KNOW...

1

Silence is best, or a gentle background hum. 'Coffee shop noise' is great!

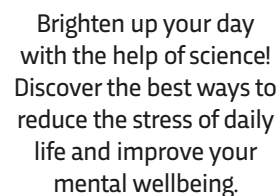
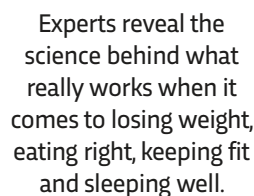
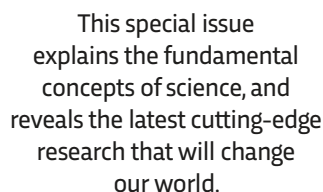
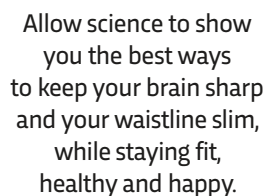
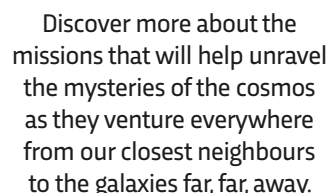
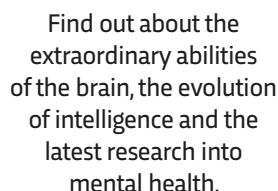
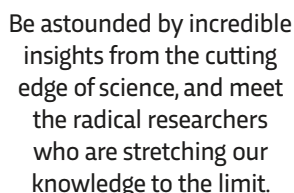
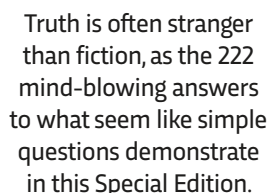
2

Switch off notifications on your phone so you can concentrate on the task at hand.

3

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